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Cambridge University science magazine

Michaelmas 2017
Issue 40
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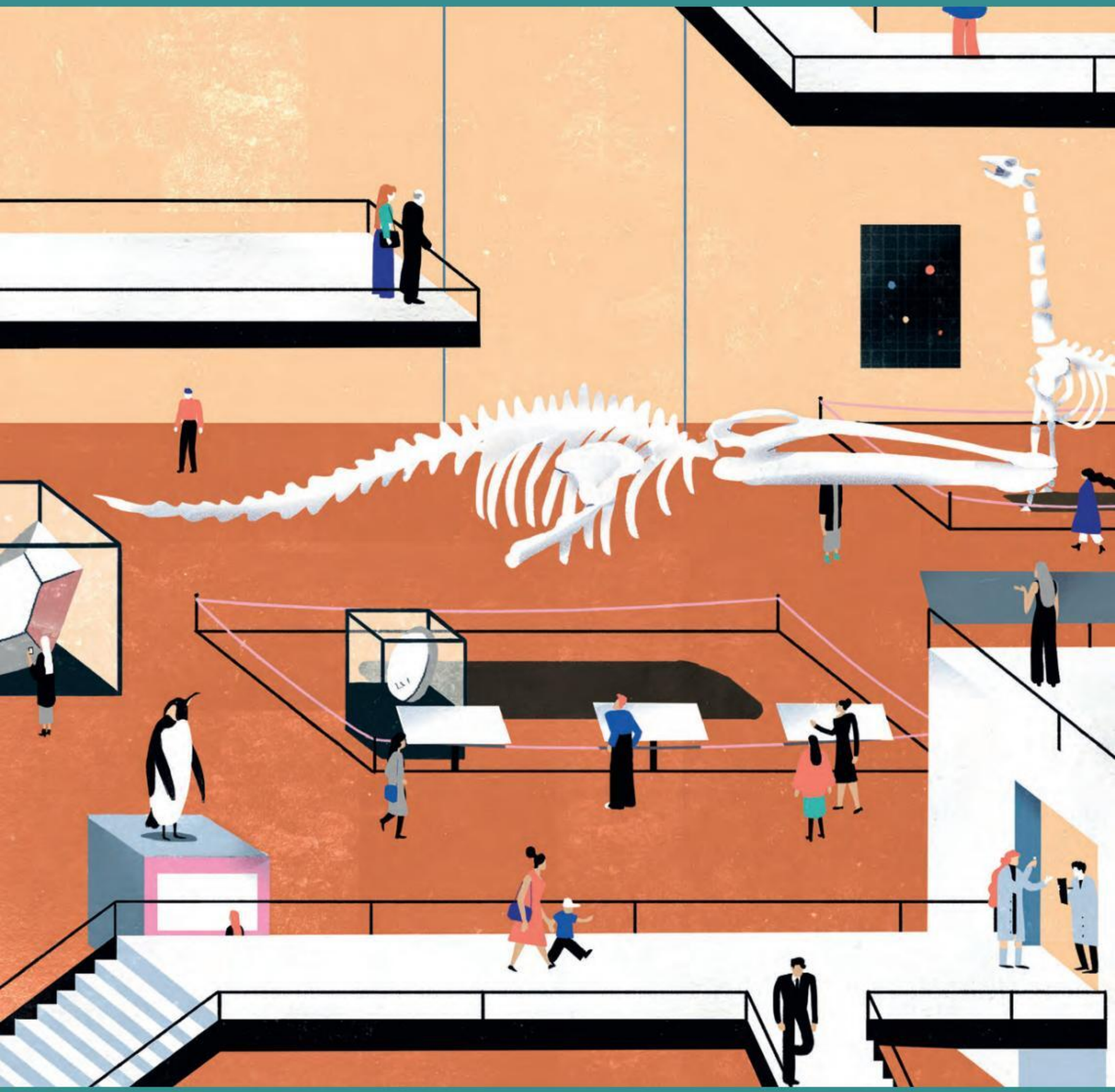

FOCUS

Sneak Peek into the Cambridge University Museum of Zoology

Space Weather • Volcanoes and Glaciers
Prosthetic Limbs • Asbestos

BlueSci

Cambridge University science magazine

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MUSEUM OF ZOOLOGY

The new museum is yearning to open its doors. Martha Dillon, Elsa Loissel, Jack McMinn and Rebecca Richmond-Smith take a peek inside

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BlueSci

BlueSci was established in 2004 to provide a student forum for science communication. As the longest running science magazine in Cambridge, *BlueSci* publishes the best science writing from across the University each term. We combine high quality writing with stunning images to provide fascinating yet accessible science to everyone. But *BlueSci* does not stop there. At *www.bluesci.org*, we have extra articles, regular news stories, podcasts and science films to inform and entertain between print issues. Produced entirely by members of the University, the diversity of expertise and talent combine to produce a unique science experience.

Issue 40: Michaelmas 2017

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Cambridge University Students' Union

The Future is History

MANY GOVERNMENTS TODAY make it a priority to invest in the education of new scientists. Is it for the sake and beauty of science? The likely answer is no. The aim is often to boost future innovation and technology; science in society today seems resolutely turned towards the future and how to concretely improve it.

Yet, as this issue will explore, science has much to learn from exploring the past - sometimes its own. In fact, our first stop will be the University of Cambridge Museum of Zoology, which mobilises its specimens from the past to further research and also displays current scientific endeavour. This is the theme of our FOCUS piece, where we find out more about the history and redevelopment of the Museum, asking how it keeps a snapshot of the past and a record of planetary biodiversity whilst helping people learn about history and remaining an active research tool for many researchers.

Next, we will explore how the past holds the key to a better understanding of a possible future for humankind. Rachael Rhodes investigates the last interglacial period, and what it can tell us about our future climate; Victoria Honour sheds light on how new information about past volcanic eruptions can be gathered, and what it means for predicting new disasters; Ramya Gurunathan scrutinizes the rise and fall of asbestos as a building material, and draws lessons from that public health disaster.

Perhaps more in line with altruistic motivations of furthering science, our writers also contemplate a world of "what ifs": what if, as Siân Emma Davies explores with Dr Max Ortiz Catalan, we could one day treat phantom limb pain? What if, wonders Tess Garrud, we could take preventative medicine into the womb, and give our children better chances even before they are born? What if we could foresee space weather, asks Ianto Cannon, or mathematically model Nature, as Stephen Cole explains?

Finally, I would like to thank our writers, editors, illustrators and producers for their continuous efforts and the resulting issue 40 of Bluesci. A special thanks should be extended to Elsa Loissel, for her phenomenal support and help during what has been a wonderful adventure. We hope that you enjoy your reading, and perhaps that some of you will feel inspired to join us in the future

Rebecca Richmond-Smith
Issue 40 Editor

On the Cover

This issue's cover looks at a museum through the mind's eye. Museums are primarily places of learning and education, wonderful environments within which one can lose oneself. We can be temporarily transported to anywhere in the world, at any point in history. Yet, museums should not strictly be places of antiquation; it is permissible for a museum to maintain pace with changing technologies, to occasionally take a breather and renovate - as we are currently seeing with the Cambridge University Museum of Zoology. What is of supreme importance is the continued maintenance and conservation of the myriad collections under the care of the museum. This process is aided greatly by this current restoration and rejuvenation project, alongside its expansion. A good museums is not just a place of quiet contemplation, but one that provokes discussion and conversation just as much as thought and observation. Museums should be meeting places wherein people of all levels of familiarity with the subject are free to share their interpretations and knowledge. For this to be successful, people of all ages and dispositions must be drawn in or introduced, and this process must be guided by the careful display of information, in words as well as in art and interactive media. The team at the Cambridge University Museum of Zoology are well aware of these factors, and it is their aim to create a new incarnation of the museum which will capture young imaginations whilst still feeding the older minds. One of the points that excites me most, and that also sets apart this particular museum from some of its larger counterparts in the United Kingdom is its unique relationship with the university - it functions simultaneously as a research centre for students and a public space, which breathes a great gust of life into its collection, along whose currents a sense of continual progress and constant motion can be detected

Neil Hampshire
www.neilhampshire.com

News

Low-cost, non-toxic lead alternative yields next generation solar cells

In May this year, solar panels provided nearly a quarter of the UK's energy needs, breaking new records and demonstrating their potential for taking over from non-renewable sources in the energy grid. In fact, last summer, solar energy provided more power than the UK's ten coal-fired power stations. Most solar panels are currently made from silicon, yet the cost of production means solar energy is not as widespread as it could be. Conventional silicon solar panels could soon be replaced by perovskite ones, which would significantly cut both cost and energy requirements of the production of solar cells. However, scientists have been concerned by the safety of these solar cells, as they contain toxic compounds such as lead-halide. In a recent study, researchers at the University of Cambridge, in collaboration with MIT, have found that perovskite cells made from bismuth, which is adjacent to lead in the periodic table, are just as efficient as lead ones but, importantly, are non-toxic. This makes bismuth-based perovskites a promising alternative, especially because they have the potential to be manufactured at low cost using existing manufacturing techniques. This high cost of traditional solar cells is a result of the low 'defect tolerance' of silicon, which means the required levels of purity are expensive to attain. Perovskite solar cells are less defect-sensitive, making them cheaper to produce. In the last few years they have reached and even surpassed the efficiency level of silicon, and have been tagged as the next-generation of solar-cells. Bismuth oxiodides, with their high defect tolerance and non-toxicity, have "real practical potential" according to Professor Judith Driscoll of the Department of Materials Science and Metallurgy, and they could be the alternative to lead that solar cell researchers have been seeking to make perovskite solar cells successful **EB**

Check out www.bluesci.org, our Facebook page or @BlueSci on Twitter for regular science news

Novel technique promises inexpensive solution to Weil's diagnosis

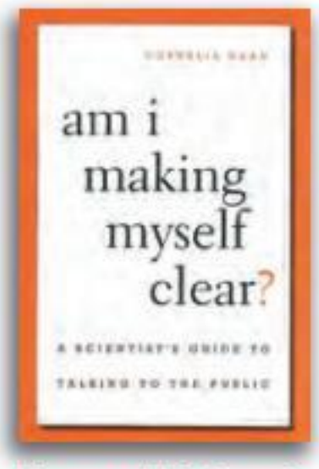
Fast, affordable testing for a potentially fatal illness may soon be possible thanks to an international collaboration between the University of Cambridge and The West African Centre for Cell Biology of Infectious Pathogens. Weil's disease or Leptospirosis is a bacterial infection caused by *Leptospira*, and is easily spread via food and water supplies contaminated by infected animals. It is challenging to diagnose because infected individuals present with symptoms such as headache, fever and jaundice, which are common to many diseases including dengue fever and HIV. Prescribing the wrong treatment can have severe consequences as, untreated, Leptospirosis can result in kidney damage, liver failure and even death. Current diagnostic tests for Weil's involve complex machinery and expensive reagents, the latter often being perishable. In developing countries, lack of equipment and high cost often make these tests unusable. Considering that the incidence of Leptospirosis in Africa is 190 times greater than that in Europe, cheap and rapid testing is key to ensuring appropriate treatment (World Health Organisation, 2011). By using techniques that allow sampling of the infectious organism and testing on the same diagnostic strip, the researchers hope that accurate identification will be possible using something analogous to a pregnancy test. The collaboration aims to design testing kits that can be produced locally for less than a dollar. Whether this will come to fruiting remains to be seen, as a prototype is not due until 2018. However, this development certainly holds the promise of improved accuracy of diagnoses, correct treatment and therefore improved survival rates **AB**

The silkworm of *Bombyx mori*

Silk 'micrococoons' offer new method for antibody delivery

Biodegradable silk 'micrococoons' provide a new method for antibody delivery. In a recently published study, researchers at the University of Cambridge have created microscopic silk cocoons that can be used to house a variety of sensitive chemicals. Some otherwise highly efficient therapeutics such as antibodies can be unstable at working concentrations. Indeed, many potential therapeutics do not move into clinical trials, simply because of issues with stability. These novel degradable silk cocoons could prevent degradation or aggregation, improving the stability of such molecules, and providing a potential method of drug delivery previously impossible. In this study, Cambridge University researchers successfully housed an antibody within these cocoons, released it, and were able to preserve its full functional activity. This particular antibody might prove to be a potential therapeutic for Parkinson's disease. Silk cocoons are, in nature, spun by silkworms such as *Bombyx mori*. Silk originally starts as a liquid inside the silkworm and is turned into a solid thread by stretching the proteins inside a microscopic tube in the worm; this process is commonly referred to as 'spinning'. Similar to how the silkworm produces silk, researchers produced an artificial microscopic spinning duct to stretch the liquid proteins and make threads which they then shaped into minuscule cocoons. Conventionally, delivery capsules are made from synthetic polymers. Silk cocoons, in comparison, are less energetically costly to produce, biocompatible, and biodegradable. These capsules have the potential to not only extend the longevity of many antibodies, but also the scope of available antibodies. Whilst further research is required to understand the behaviour of such cocoons in the human body, the creation of these micrococoons unveils new possibilities for therapeutics **LS**

Reviews



Harvard University Press, 2009

Am I Making Myself Clear? - Cornelia Dean

Cornelia Dean has spent 30 years as a science journalist at the New York Times, and in this 'scientist's guide to talking to the public,' she breaks down the intuition around science communication which she has developed in that time. The book is a lean, quick-moving compilation of tips for research scientists looking to explain their work to a non-technical audience-- be it lawmakers, reporters, or the general public. Each piece of advice she provides is justified by illustrative (and often highly amusing) testimonies and anecdotes from both scientists and the non-scientists trying to understand them. Chapters are organized either by different mediums of communication, (i.e. radio, film, books), or by audience (i.e. politician, civilian, jury). Dean impresses upon the reader the importance of science outreach, while demonstrating her keen awareness of the time constraints and stresses of life as a research scientist. Her advice, therefore, always aims for both efficacy and feasibility. When should you write a book? Only when you can't think of any other way to tell your story. What do you do when a reporter cold-calls you? Ask for time to collect your thoughts and offer to call him/her back. Anyone interested in communicating his/her science to general audiences, who feels nervous about being ignored, mistaken, or misrepresented, ought to consult this handy guide **RG**

Anyone interested in communicating their science to general audiences, who feels nervous about being ignored, mistaken, or misrepresented, ought to consult this handy guide

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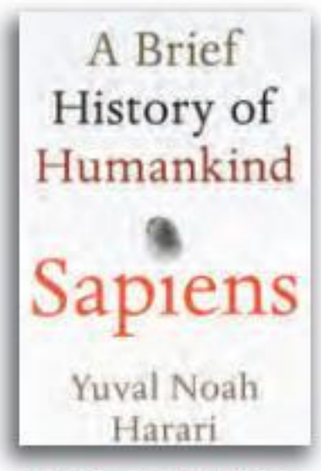
Viking, 2013

Stuff Matters: The Strange Stories of the Marvellous Materials that Shape Our Man-made World - Mark Miodownik

What is the world around us made of? In his breakthrough bestseller *Stuff Matters*, Mark Miodownik sheds light on this very question, looking at the history and structure of materials that we use everyday. He uses a framework of scientific and historical facts, and weaves it through with personal encounters with the materials. He gives many materials, both mundane and and cutting edge, a voice. Discover the surprising role bacteria play in self-healing concrete and the secrets of the structure of chocolate crystals that chocolatiers do not usually share. Hand-drawn diagrams and humorous anecdotes, together with Miodownik's accessible writing style, will make your journey through the world of marvellous materials swift and smooth **NM**

Without a shadow of doubt, Stuff Matters is a love potion to fall for materials science!

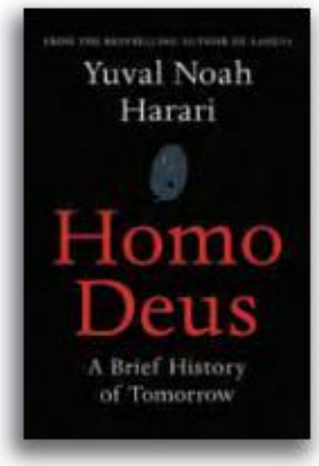


Harper Collins, 2014

Sapiens: A Brief History of Humankind and *Homo Deus: A Brief History of Tomorrow* - Yuval Noah Harari

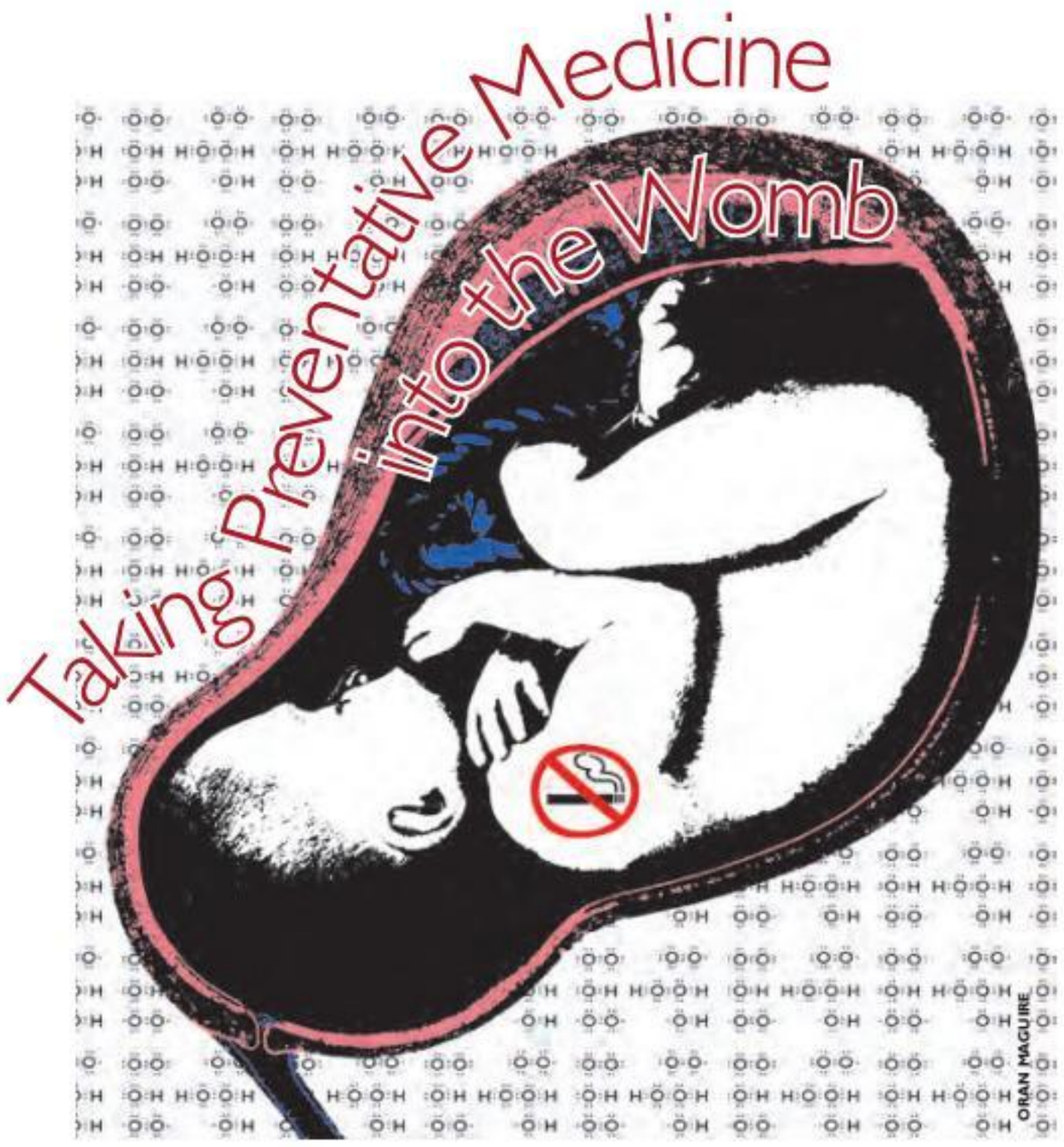
In *Sapiens*, Harari describes how the history of *Homo sapiens* - the 'wise man' - has been shaped by three major revolutions: the Cognitive Revolution (70,000 years ago), the Agricultural Revolution (10,000 years ago) and the Scientific Revolution (500 years ago). Harari argues that *Homo sapiens* are not more intelligent, genetically different and happier than our ancestors - our key to innovation was language. These revolutions have empowered humans to do something no other form of life has done - to create and connect abstract ideas, social connections and networks. Harari tackles topics ranging from religion to political reform, genetics to the science of happiness, and ancient history to future economy. However, paralleling his academic research, Harari focuses on macro-historical questions such as the relationship between history and biology, the differences between *Homo sapiens* and other animals, and how the impact of *Homo sapiens* on today's world is more powerful than the past. Harari predicts our race as we know it will not survive to witness the end of the millenia and in the sequel, *Homo Deus*, he brings us into the present and just beyond: us at the height of our powers. In order to both transcend the biological limitations of our 'human condition' and prevent our inevitable downfall, we must use our unparalleled ability to control the world, our networks and technology, to defy natural selection and guide our own evolution. While exploring the relationships between humans and technology, Harari asserts that 'organisms are algorithms'. Embracing a new age and new 'Dataist' philosophy - where all of humanity's thoughts, behaviours, art, science and relationships are reduced to bits of code - is not demeaning but empowering. The next stage of human history will not only involve biological and technological changes but also changes in human consciousness and identity, questioning the very meaning of 'human'. While speculating what humans could become and what we could realistically achieve with our predicted technology and knowledge, Harari also poetically discusses the threats of Artificial Intelligence. "Once artificial intelligence surpasses human intelligence," Harari writes, "it might simply exterminate mankind" **LM**

Exploring our past, current capabilities, and uncertain future, Harari discovers the answer to one of our most fundamental questions: "What makes us human?" Nothing but the capability to make ourselves Gods."



Harvill Secker, 2016

Taking Preventative Medicine into the Womb



Tess Garrud explores how 'developmental programming' could help produce healthier children

ONE OF THE GREATEST BURDENS faced by modern healthcare is that of treating non-communicable diseases – so called 'lifestyle diseases'. This term encompasses any condition not passed person to person. The most well-known and potentially devastating in the UK are cardiovascular disease and type 2 diabetes. In fact, cardiovascular disease is the greatest killer in the world, accounting for 31% of all deaths in 2012 according to the World Health Organisation. Worryingly, incidences of these diseases are increasing in the Western world, and many doctors consider us to be amidst an epidemic. We all know that our risk of suffering from one of these conditions can be affected by our genetic background and lifestyle (e.g. smoking, diet). But, what if our chance of developing one of these diseases is already drastically different from that of our peers before we are even born?

For a long time there was anecdotal evidence that those who are born small may be more likely to have cardiovascular problems as an adult. In 1989, an epidemiologist called David Barker decided to investigate this phenomenon. The first step in his research was to assess a group of middle aged men in Hertfordshire whose birth weights had been recorded by midwives. He argued that birth weight could be thought of as a simple proxy measure for how good pregnancy had been (a low birth weight might indicate that there was a problem during pregnancy). Barker found that those men who were born small were more likely to die from having a heart attack. This was the first evidence that the environment encountered in our very early life can exert a profound influence on the risk of disease in adult life, an effect which is now known as developmental programming.

Since Barker's original work, a plethora of both human and animal data has arisen which demonstrates a link between pregnancy and risk of non-communicable disease. For example, in sheep studies, if the mother does not have enough nutrients during pregnancy then her offspring have lower birth weights and are more likely to develop high blood pressure as adults. Conversely if a ewe is fed a high fat diet during pregnancy, then her offspring have larger birth weights and are more likely to display insulin resistance (a hallmark of type 2 diabetes) in adulthood. The situation in humans appears to reflect these animal studies. Data from the Dutch 'Hunger Winter', in which Dutch populations were starved by the invading Nazi forces during 1944-45(limited to as low as 500kcal a day), shows that individuals who were exposed to the famine in utero were more likely to suffer from hypertension and insulin resistance at middle-age, compared to age and weight matched controls. In the opposite situation, there is evidence that the children of obese mothers are more likely to have increased adiposity (fat storage) and suffer from glucose intolerance. In one study, the offspring born to obese mothers both before and after maternal bariatric surgery were studied. Those born prior to the surgery had greater abdominal fat and performed worse in glucose tolerance tests as teenagers than did their siblings born after the surgery. The scientific evidence extends far beyond examples of just maternal nutrition and we now know that multiple early factors can act to alter the likelihood of adult disease.

All of this leads to a concerning picture. If we are born with an inherent risk of suffering from these diseases and are then exposed to the western diet and lifestyle, how can we avoid these conditions? If we could understand the mechanisms behinds these effects, theoretically we could intervene.

So, what are the realistic possibilities of developing treatments? Some research groups have begun to untangle the mechanisms behind specific problems in pregnancy so they can address this question. Professor Sue Ozanne of the Institute of Metabolic Science is interested in the metabolic and cardiovascular health of an individual, if their mum was obese during

pregnancy. Research in her group using a mouse model has shown that if obese mothers are given moderate amounts of exercise on a treadmill during pregnancy, then the negative effects on their children can be avoided. It appears that the link in this situation may be maternal insulin levels. Insulin levels are higher in obese mothers but reduce when they are given exercise. Prof. Ozanne highlights the implications and potential of these results:

"As well as providing mechanistic insight, our findings have important translational implications as they propose that in situations of maternal obesity, it may be better to focus on interventions that improve metabolic fitness rather than control maternal body weight … Our findings suggest that providing women with the tools and information on the benefits of incorporating an active lifestyle prior to, and during, pregnancy could have huge potential long-term benefits in preventing transmission of obesity from mother to child."

What about problems in pregnancy that cannot be solved by lifestyle changes as simple as more exercise? Professor Dino Giussani of the Department of Physiology, Development, & Neuroscience has spent much of his career studying what happens when the unborn baby is exposed to a reduction in blood oxygen levels. His group have demonstrated in rat and sheep models that if the mother is exposed to a low oxygen environment during pregnancy (such as being at high altitude) then the offspring have increased risk of cardiovascular disease in adulthood. However, this can be prevented if an antioxidant such as Vitamin C is given during pregnancy. Antioxidants reduce oxidative stress, which increases when there is insufficient oxygen, and may thus protect the developing heart.

So overall, the future does not look quite so bleak. The ever-expanding research area of developmental programming is shining light onto the possibilities of bringing preventative medicine into the womb and protecting our children's future health. The more we begin to understand how changes in pregnancy affect the developing child, the more successfully we can act to ensure that our early life is as fruitful as possible β

Tess Garrud is a 1st year PhD student studying foetal cardiovascular physiology in the Department of Physiology, Development, & Neuroscience. Artwork by Oran Maguire

A growing body of evidence suggests that there is also a paternal influence on the offspring's future health. The father's occupational exposure to carcinogenic substances (e.g. paints, dyes, hydrocarbons) has been shown to increase risk of his child's early death from malignant causes

The Emergence of Agriculture in Lejja Southeastern Nigeria

Chioma Vivian Ngonadi discusses her archaeobotanical research

FOOD PRODUCTION AND METAL WORKING are believed to be one of the most important progressions in African prehistory. The clearance of the forest, the working of the wood, the quarrying and carving of stones, the cultivation of the ground and the slaughtering of enemies were all achieved more efficiently and with less effort by people who are better equipped with iron tools and weapons. In Lejja-Igboland, southeastern Nigeria, iron smelting is an indigenous craft specialisation that flourished on an industrial scale from around 2000 BC and lasted until the later part of the twentieth century. Evidence in the form of relic furnaces and extensive slag and tuyere remains are widely visible in the landscape today. The vast number of slag blocks on the surface reveals that iron working in this region was a highly sophisticated, long-lived and well-developed tradition with techniques that involved relatively large-scale metal production.

For decades, archaeological investigations in Lejja has focused mainly on the technology of iron working production and symbolic and political stratification. However, the bulk of past research has largely overlooked the farming communities themselves who utilised and may have fashioned such iron technologies. No systematic survey has been undertaken to locate and explore associated settlement sites, and consequently we know very little about the people and economy of the area across this period of iron working.

My PhD research at the Department of Archaeology and Anthropology, University of Cambridge, aims to identify the earliest evidence for agricultural production in Lejja. The study also intends to analyse the relationship between the iron working sites and agriculture in the deeper past by establishing a baseline chronological sequence and essential economic characteristics from archaeobotanical data via flotation and soil sampling. These archaeobotanical data will then be used in identifying whether these early iron workers (or the people at the metal working sites) were the direct food producers or acquired food stuff from their neighbours through exchange mechanism.

My method builds on tried and tested combined archaeological and anthropological techniques developed in Africa and studies of settlement and domestic life conducted in the neighbouring region of Nigeria and other West African countries. Overall the study will contribute to the growing bodies of knowledge concerning the development, variations and sophistication of African farming systems and plant domestication. Additionally, it will attempt to rewrite the deep time history of Igboland, Nigeria and West Africa.

The transition from hunting and gathering to agriculture is often regarded as the most significant threshold in recent human cultural evolution, allowing unprecedented population growth and providing the potential basis or surplus production that underpinned urbanism and civilization. For this reason, numerous explanations have been proposed for the beginning of agriculture, most of them deductive and only minimally constrained by available information. Humans have often been viewed as forced into agriculture by the uncontrollable circumstance of nature such as climate change, environmental degradation or an inherent growth in population. These activities transformed and changed the relationship between humankind, its physical and cultural environment. Today, the consensus view of origins and spread of agriculture is an outgrowth of these perspectives. However, humans may have been active players in the process; changes in the social, economic and ideological aspects of human society were significant forces in bringing about the transition, something that archaeological investigations in Lejja might help to pick apart

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Chioma Vivian Ngonadi is a 2nd year PhD student at the Department of Archaeology and Anthropology

CHIOMA NGONADI

A vast number of slag blocks, iron working residues, adorn the landscape

Space Weather

Ianto Cannon writes about storms in space and how we can predict them

1,500,000 KILOMETRES (930,000 miles) from Earth orbits a satellite whose sole mission is to protect the Earth. Its name is the Deep Space Climate Observatory (DSCOVR) satellite and its role to monitor space weather, variations in the Solar System such as the solar wind.

At the end of October 2003, the city of Malmö in Sweden suffered an hour long blackout. Around the same time, electricity transformers in South Africa were severely damaged. Aurorae Borealis were seen as far south as Portugal, and 47 satellites reported malfunctions. In fact, communication was permanently lost with a $640 million weather satellite known as Midori 2. The culprit? The "Halloween storm", one of the largest solar storms since the beginning of the space age in the 1960s.

A coronal mass ejection is an eruption of matter from the Sun's surface. It occurs when some of the Sun's magnetic field lines stretch and snap open, ejecting billions of tons of electrons, protons, and helium nuclei toward the Earth. Thankfully, our planet is protected from these damaging particles by its magnetic field. It traps charged particles into two torus shaped bands that encircle our planet, called the Van Allen belts.

During the Halloween Storm - or any major coronal mass ejection, large numbers of electrons are injected into these belts. Some of the electrons spiral down Earth's magnetic field lines, colliding with atoms in the upper atmosphere. Excited oxygen atoms produce red or green light, and nitrogen molecules glow crimson, lighting up the night sky with aurorae.

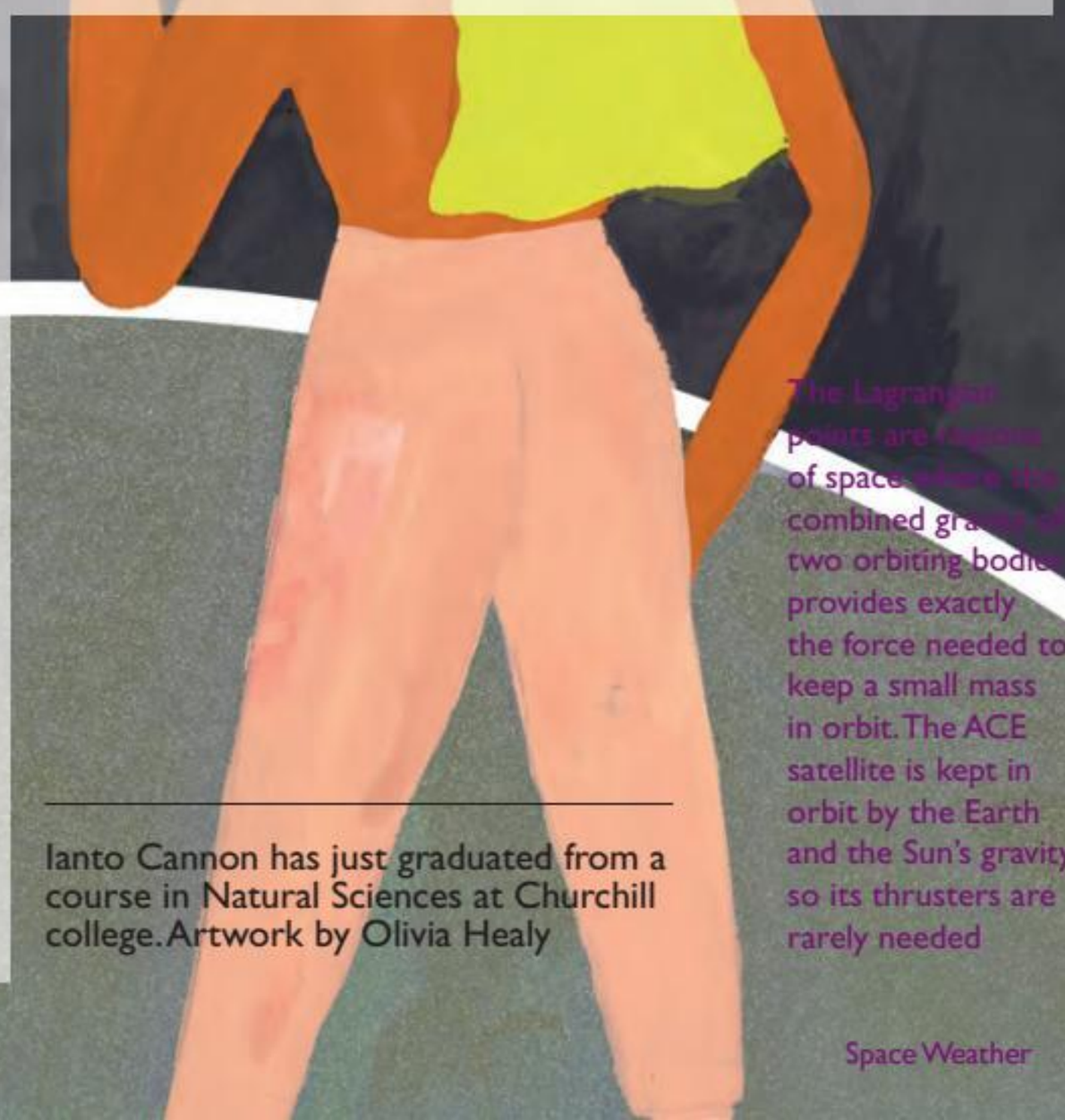
The spiralling electrons emit low frequency radio signals (known as chorus waves) due to their motion. The chorus waves accelerate other electrons in the outer Van Allen belt to high energies. A typical high energy electron moves at 80% of the speed of light and circles the Earth every 15 minutes. High energy electrons can easily penetrate satellite shielding, leading to a charge build-up on components, culminating in a spark. Arcing between conductors melts insulating materials, causing circuits to fail. There are around 1000 satellites orbiting in the belts, all of which are at risk of damage during solar storms.

Faraday's law of induction states that modifications in the magnetic field will produce currents in electrical circuits. This means changes in high energy electrons circling Earth can induce surges in power grids on Earth's surface. In Malmö, transformers were damaged: for around an hour thousands of people were without electricity, trains halted, and the fire brigade were called out to seven locations to rescue people trapped in elevators. If a large solar storm were to knock out parts of the power grid in North America, estimates of the total cost are in the billions of dollars.

Fortunately, damage to satellites can be minimised if the location of high energy electrons is known beforehand. Orbit manoeuvres can be rescheduled, nonessential components can be switched off, and operators can provide back up satellites in order to reroute communications. Large power surges can be avoided by temporarily separating the power grid into smaller sections, and reducing the load on individual transformers.

This is where DSCOVR comes to play. It is positioned at the Lagrangian point between the Sun and the Earth. The DSCOVR's measurements of the solar wind and magnetic field give us around three hours warning before these high energy electrons enter the Van Allen belts. Hence we can use the maps to create a simulation of the belts three hours ahead, predicting the locations of these high energy electrons. This forecast allows surge protection to be put in place. If there is a large flare, the communication link can be lost, so the anticipating system also relies on chorus wave and electron measurements from other satellites.

Our dependence on satellites is continually growing, yet there may be more incidences of these larger flares as we exit the quiet phase of the 11 year solar cycle. Due to the infancy of the satellite industry, we have few records of large storms. The Halloween Storm may have been a freak occurrence, or perhaps there are far larger events of this type in store for us. Space weather forecasts are essential for life as we know it to continue undisrupted, safe from the tempests of the universe β



The Lagrangian points are regions of space where the combined gravity of two orbiting bodies provides exactly the force needed to keep a small mass in orbit. The ACE satellite is kept in orbit by the Earth and the Sun's gravity, so its thrusters are rarely needed

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Ianto Cannon has just graduated from a course in Natural Sciences at Churchill college. Artwork by Olivia Healy

Warm and Cosy: How Organisms Cope with Extreme Cold

Georgia Tindale discusses Antarctic animals' innovative adaptations for tackling freezing temperatures

FOR CAMBRIDGE STUDENTS, the winter months involve finally wearing that college sweatshirt and scarf bought in Freshers' Week, an even greater reluctance than usual to attend 9am lectures, and significantly increased hibernation periods. In the natural world, animals must cope with conditions of extreme cold which are even worse than Cambridge's notorious Siberian winds. In Antarctica, for example, temperatures range between -40°C and +10°C across large areas of the continent, with the average remaining below freezing throughout the year. Antarctic animals have had to evolve innovative and unexpected ways to cope with this cold. Two creatures exhibiting some of the more ingenious tricks are Emperor penguins, whose 'cold coats' paradoxically keep them warm, and microscopic nematode worms, which can produce their own 'antifreeze'.

In addition to their obvious anatomical and behavioural adaptations to cope with extreme cold (layers of blubber, windproof and waterproof feathers and their formation of huddles with other penguins), researchers from the University of Glasgow have discovered that Emperor penguins have a 'cold coat' of feathers which helps to keep them warm. According to a press release from the University of Glasgow, scientists from Glasgow's Institute of Biodiversity, Animal Health & Comparative Medicine working with the Université de Strasbourg discovered this 'cold coat' when using thermal imaging techniques to measure the surface temperature of penguins in Adélie Land, Antarctica. The coat is so named because the temperature of the feathers that it consists of was, on average, four degrees cooler than the air surrounding the penguins. Computer simulations performed by the researchers indicated that this 'cold coat' could allow the penguins to gain back some heat from the warmer air which circulates around them. Although this heat is unlikely to ever reach the penguins' skin, it could reduce the heat lost from their bodies.


CHRISTOPHER MICHEL

At first, the scientists were surprised by this seemingly counterintuitive discovery. Dr Dominic McCafferty from the University of Glasgow explains:

'Most of the body that is covered by thick plumage was found to be, on average, four degrees Celsius colder than surrounding air temperature. At first, we were very surprised by this discovery.

'But after analysing the data we realised the key to this is the temperature of the sky.

The sky has a temperature that may be more than 20 degrees colder than the surrounding air. The temperature of the plumage is therefore effectively influenced most strongly by the temperature of the sky rather than the surrounding air.'

'A similar phenomenon can be observed if you park your car in the open on a cold night. Usually you will only find frost to have formed on the roof and windscreen but the sides do not 'view' the sky and therefore are radiating to relatively warmer surroundings.'

"The same phenomenon explains why fruit can be damaged by radiative frosts when the air doesn't drop below freezing. The difference is we didn't think a warm-blooded animal could ever have an outer surface temperature that was colder than its surroundings.'

He continued: 'Antarctic penguins' plumage is so well insulated – insulation equivalent of us wearing two ski suits – that heat will be transferred very slowly to the skin surface. In this way the penguin will remain warm on the inside but the outer surface of its plumage will be extremely cold.'

However, it is not just Antarctica's bigger animals that require nifty tricks to keep warm. Moving down from moderately sized penguins, to the microscopic nematode worm, researchers at Brigham Young University (BYU) have discovered that this half-millimetre long creature can produce

its own 'antifreeze' in order to withstand Antarctica's subzero temperatures.

How does the worm achieve this? Usually, when water freezes inside a living thing, crystals of ice form. This causes damage at the cellular level, resulting in frostbite, a condition which can be fatal. Researchers from BYU have found that the nematode worm Plectus murrayi copes with this issue in a novel way.

The worm produces a special protein which, like antifreeze, may prevent these crystals from forming. As a result, its cells remain undamaged, and no frostbite occurs, allowing it to survive the extreme cold.

Not only are the worm's adaptations for coping with extreme cold impressive, they may also have major implications for future innovations in agriculture. If scientists are able to identify which genes are used by the nematode to activate its antifreeze system, this information could be used to engineer frost-resistant crops in the future.

The production of 'antifreeze' is not the only impressive thing about this microscopic creature. According to the BYU scientists' research, when groundwater dries up and conditions become inhospitable, Plectus murrayi can also dry itself out, going into 'suspended animation' until increased availability of groundwater, and hence more favourable living conditions, allows it to rehydrate and come back to life.

Byron Adams, Associate Professor of Molecular Biology at BYU, and a key researcher on the project, points to the wider implications of the worm's adaptations. He argues that this particular nematode's special genetic response to its environment means that it 'is likely to flourish as Antarctica gets wetter' due to climate change, even as other nematodes suffer.

According to a press release from BYU, Professor Adams' previous research on other Antarctic nematodes showed that temperature fluctuations due to climate change have caused a drop in population numbers for some worm species, resulting in changes to the biodiversity of the Antarctic soil. However, a similar drop in numbers of Plectus murrayi, the 'antifreeze' nematode, is unlikely to occur thanks to its unique adaptations for coping with both extreme cold and changes in water levels.

Through research such as Professor Adams', highlighting the ability of soil-dwellers like Plectus murrayi to cope with shifts in its environment, scientists may be able to predict how the composition and distribution of soil species might alter as a consequence of climate change. This information could prove fundamental to understanding the impact of climate change on soil biodiversity not just in Antarctica, but also in the wider world, with important consequences for farming practices.

As Adams says: "Understanding how the soil functions independent of plants allows us a baseline that we can later add plants to."

He continues: 'These are rudimentary first steps - the long-term goal is to be able to extend our findings to more complex ecosystems, particularly managed ecosystems. Growers want to know how climate change is going to affect their ability to grow crops. Right now we don't really know. Understanding how this works in a simple ecosystem is the first step in being able to make those predictions.'

For both the Emperor penguin and the microscopic nematode, the freezing temperatures of Antarctica pose an environmental challenge which results in extraordinary evolutionary adaptations. Whether it's the penguins' 'cold coats' which keep them cosy, or the nematode's production of antifreeze, these two creatures provide new insights into how unexpected evolutionary adaptations can be β

Georgia Tindale has an MPhil in Renaissance Literature from Girton College. Artwork by Oliver Macdonald Oulds

Other nematodes, such as the model organism *Caenorhabditis elegans* can also be frozen and thawed, and remain alive. This has proven extremely useful in biological research because *C. elegans* strains can be frozen in order to preserve them for later use or to transport them between far away labs. This helps to keep genetic mutations in different strains stable

Out of Sight, Not Out of Mind: Intractable Pain in a Phantom limb

Siân Emma Davies interviews **Dr Max Ortiz Catalan** about his new technology for treating phantom limb pain

"I DON'T CARE about not having my arm or my leg, I just don't want to have pain". Dr. Ortiz Catalan has often heard this statement throughout his career, which he dedicated to the improvement of the lives of amputee patients. His main field of research focuses on developing technology for a prosthetic device for upper arm amputees at the Chalmers University of Technology, collaborating with the Sahlgrenska University Hospital and Integrum AB in Gothenberg, Sweden. However, he has quickly discovered that some patients did not consider the loss of their limb to be the most debilitating aspect of their condition. He explains, "You can see how big a problem pain is. It very quickly becomes a priority in your life."

Many amputees suffer from phantom limb pain, which are painful sensations perceived to originate from the missing limb. Cortical reorganisation occurs after an amputation and somehow, this reorganisation becomes entangled with pain signals, giving rise to the symptoms.

Standard therapies for this condition have limited success. The most widely used treatment is mirror therapy, whereby a mirror is placed between the amputated sand the healthy limbs. The patient moves the healthy arm or leg, watching its reflection in the mirror. The idea is that over time it tricks the brain into thinking both limbs are healthy and mobile, correcting the faulty cortical signals and reducing pain. However, Dr. Ortiz Catalan explains that in mirror therapy, "everything is based on the healthy arm. [The patient] can spend hours completely disregarding the affected limb, as long as they are moving the healthy arm in front of the mirror. [The affected limb] is not involved directly in the therapy". This, Dr. Ortiz Catalan believes, is a major shortcoming to current treatments.

However, how could you engage a limb that is no longer there in therapy? Dr. Ortiz Catalan discovered that he could decode the intention of movement of the missing limb by looking at the electrical activity of remaining muscles in the stump. This opened up a range of applications; not only could this aid the movement accuracy of prosthetic devices, but also addressed the current limitations of treatments for phantom limb pain.

Dr. Ortiz Catalan's technology for prosthetics differs from conventional attachment systems in a number of ways. Firstly, the prosthetic is fully implanted; load-carrying titanium is inserted directly into the bone, which acts as a strong anchor for the prosthesis. This dramatically increases the range of motion available to the arm compared with alternative attachment systems.

Secondly, electrodes used to control the limb are implanted directly onto the nerves and muscles. This allows for a much clearer signal transfer than conventional electrodes which are attached at the surface, and therefore much more reliable movements of the prosthesis. "Of course, it is far away from a biological arm," concedes Dr. Ortiz Catalan, "we can't even compare it. But these advancements have made a big change when it comes to the functionality that it provides to the patients." Amputees are able to use their new artificial arm in their everyday lives, return to full-time work, and even engage in outdoor hobbies that they believed would have been just a fond memory post-amputation.

Direct connection between electrodes and nerves allows for bidirectional communication between the patient and the limb, using sensors embedded in the hand of the prosthesis. Patients can experience sensations in their amputated arm, which are unique and independent from their healthy arm. In addition to this sensory-motor feedback, patients also gain valuable visual feedback by constantly seeing their prosthetic move synchronously and exactly as intended. Not only does this provide patients with a renewed sense of ownership, but Dr. Ortiz Catalan also hypothesised that the ability to properly control the new robotic arm is key to taking away the phantom limb pain in these patients.

Not all patients wish to go through the intensive treatment for a fully implanted prosthetic, but pain is still a very real and dominating feature in their lives. Therefore, using the same fundamental technology of his prosthetic device, Dr. Ortiz Catalan designed a new therapy for these individuals. "We have this technology that could predict intention of movement of the phantom limb […]so I thought to mix this with an augmented reality". Patients can sit in front of a webcam, watching a live video of themselves. A virtual limb however, is displayed in place of the amputated limb. Via surface electrodes placed on the stump, Dr. Ortiz Catalan's software executes the movement of the virtual arm, as intended by the patient's phantom limb. "It's like a mirror, but it has this virtual portion that the patients can control voluntarily using their stump". After initial training, the therapy involves controlling a virtual car around a race course using their phantom limb - a far more exciting alternative to the monotonous tasks of mirror therapy.

The main distinction between this therapy and conventional treatments is that patients need to make an active effort to engage their phantom limb to control the game. For a condition that has arisen through a re-wiring of the brain, Dr. Ortiz Catalan believes this aspect is a necessity for treatment to be effective. "Similar areas are activated when you imagine and when you execute [movements], but they don't activate to the

same degree and other sub-cortical areas don't get involved in imagery. We really think that this difference between executing the movement and just imagining it is important," he explains. "What we are trying to do with this therapy is to normalise the brain state. If you put to work the [brain] circuitry in its original job, then it will stop processing pain".

Since its pilot, the software has been tested on dozens of patients with chronic, treatment-resistant, phantom limb pain. Results showed a dramatic and sustained reduction of pain for patients, some of which had been suffering for decades. "For the first patient, we saw such a big improvement in his quality of life" Dr. Ortiz Catalan reminisces, "it was a very moving thing to see how much it helped this person". The technology is portable for people to use at home when needed, and Dr. Ortiz Catalan has made it open source. "I'm particularly interested for other people to use it and find out if it is really useful."

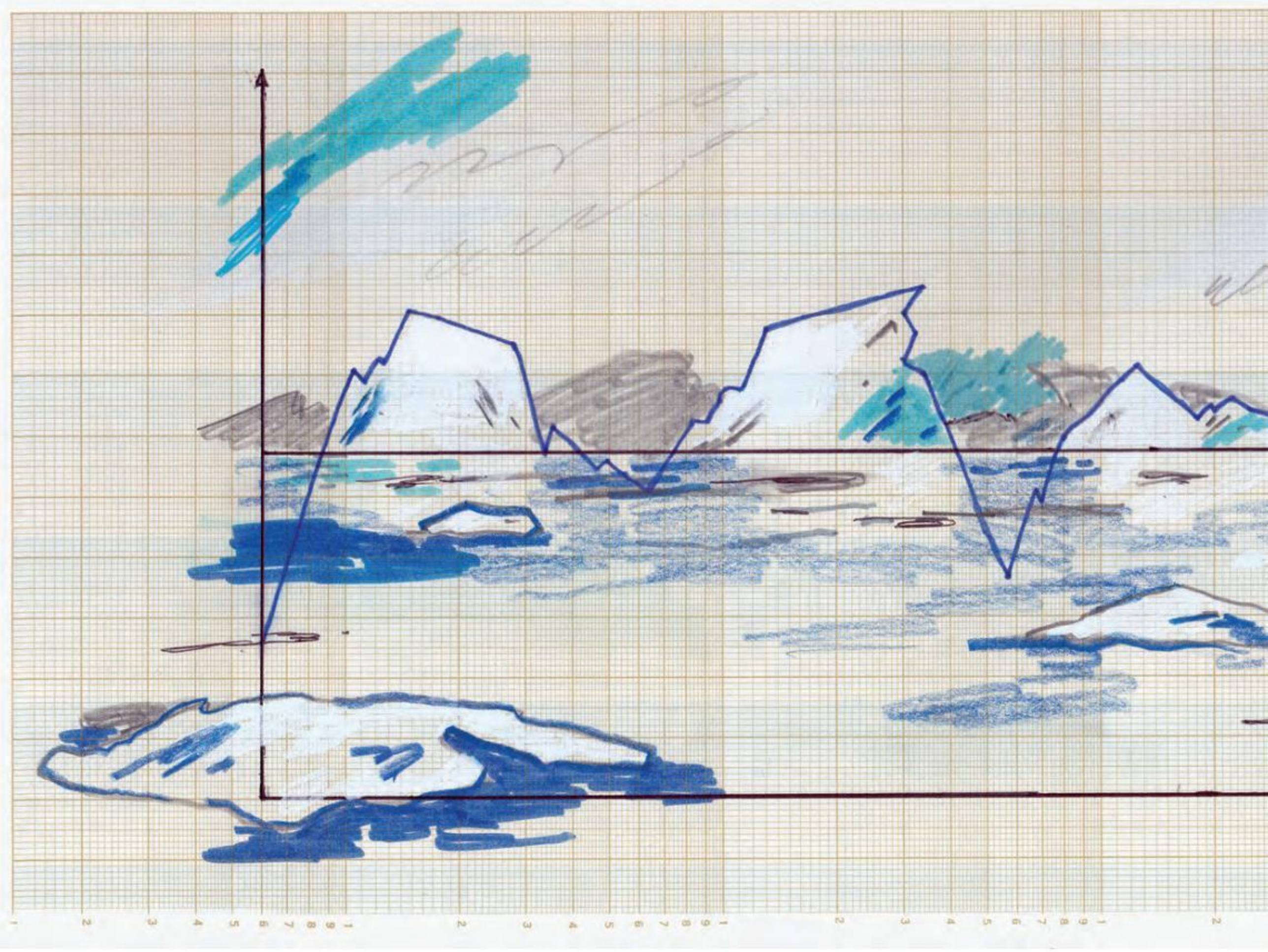
Dr. Ortiz Catalan and his team plan to take this work further, in a larger clinical trial investigating phantom limb pain in both upper and lower limb amputations. He hopes it will provide further evidence for the effectiveness of the therapy, and since this interview they have recently published work showing proof-of-concept for the therapy in lower-limb amputees. He also has in mind to identify the specific mechanisms in the nervous system that underlie the therapeutic effects of his technology, through the use of brain imaging. Beyond amputees patients, this approach could also help other patients, like those recovering from stroke; a project that is already being explored through collaboration.

The sophistication of engineering and the depth of knowledge of the nervous system involved in these treatments is remarkable, but Dr. Ortiz Catalan's technology goes that step further. Put succinctly, "beyond being a cool new technology, I see it as a tool for therapies". Giving amputees a renewed sense of independence with a cutting-edge prosthetic limb and further take away suffering of phantom limb pain is an incredible feat. No doubt, this is just the beginning of what is possible to achieve when technological development is guided by a passion to improve quality of life for patients. β

Siân Emma Davies is a 3rd Year PhD Student in the Department of Psychiatry at Jesus College. Artwork by Nina Carter

If you are interested in Dr Ortiz Catalan's work, you can get updates on the lab's current research on:
Twitter: @ChalmersBNL
Facebook: https://www.facebook.com/ChalmersBNL/

"What we are trying to do with this therapy is to normalise the brain state. If you put to work the [brain] circuitry in its original job, then it will stop processing pain"



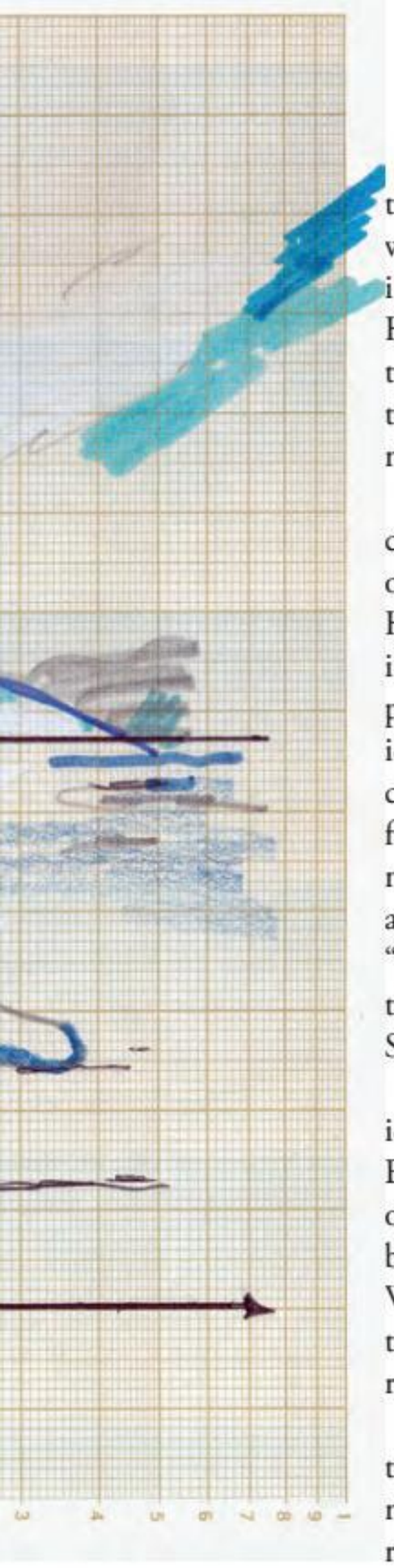
How Long Until the Ice Breaks?

Rachael Rhodes investigates the future of global sea level by looking back at the past

EVERY MORNING I WATCH global sea level rise. As I pour boiling water into my breakfast mug, the world map decorating the outside of it transforms. As the box this wonderful gift arrived in declares, it's 'Bye-bye Belgium' and 'So long Florida'. A fun way to start the day, but also a little depressing. It makes me curious to know what will really happen to global sea level as we continue to emit greenhouse gases and warm our planet.

Over the last century, global sea level has risen by 0.19 m. This rise is linked to melting alpine glaciers and the expansion of oceans as they absorb heat. Together, these two phenomena could cause 1–1.5 m of sea level rise, a significant amount, but not enough to lose Belgium and Florida. The huge rise in sea level featured on my breakfast mug can only be achieved by melting the major ice sheets on Greenland and Antarctica. Could this be a feature of our future? Predicting the future of ice sheets is tricky. There is uncertainty about how the climate is going to evolve: it is going to get warmer, but how quickly? And by how much? Then there is the question of how the continental ice sheets will react: gradual retreat or catastrophic collapse? Many Earth scientists, including Dr. Max Holloway at the British Antarctic Survey in Cambridge, look back to the past to help predict the future.

Holloway's research focuses on how ice sheets behaved during the last interglacial period. As the name suggests, this is the warm period (interglacial) prior to our current one, the Holocene. It began roughly 130 thousand years ago. "The last interglacial period is a great analogue for the climate situation we're heading for before the end of the century, particularly in the polar regions," says Holloway. "Antarctic temperatures were about 3–5°C warmer



than in pre-industrial times and Greenland was 5–8°C warmer". What does the last interglacial tell us about future sea level? Holloway replies: "all the evidence points to last interglacial sea levels 6–9 m higher than pre-industrial." No doubt there that melting ice sheets were involved.

Melting the entire Greenland ice sheet could have feasibly caused the 6–9 m of sea level rise observed. However, as Holloway explains, it did not disappear in the last interglacial: "Ice core drilling projects have recovered last interglacial ice at several Greenland locations. These constraints limit the sea level contribution from the Greenland ice sheet to a maximum of 3.5 m." How do we then account for the additional sea level rise? "It has to have come from Antarctica and the main suspect is the West Antarctic Ice Sheet," continues Holloway.

The Antarctic continent has two major ice sheets: East and West. While most of the East Antarctic Ice Sheet is on land, much of the West Antarctic Ice Sheet is grounded below sea level. This is thought to make the West Antarctic Ice Sheet more vulnerable to warming temperatures and susceptible to rapid disintegration.

Scientists study how Antarctic temperatures varied in the past by measuring chemical signals in ice cores retrieved from the ice sheets. Essentially, the proportion of water molecules with different masses making up the ice changes with temperature. There are more of the relatively light water molecules in cold temperatures and more of the relatively heavy water molecules in warm temperatures.

In East Antarctic ice core records, heavy water molecules peak 128,000 years ago. "This is when it was assumed the West Antarctic Ice Sheet collapsed," explains Holloway. "Peak warmth in Antarctica, at the beginning of the interglacial". To test this hypothesis Holloway used a global climate model with a difference. His numerical model predicts the mass of water molecules deposited at ice core sites across East Antarctica, meaning he can compare his model output directly to ice core data. "I set up different virtual reality scenarios in which the ice sheet collapsed, let them run in the climate model, and looked to see which scenario produced results matching the ice cores," explains Holloway.

The results, published last year in the journal *Nature Communications*, were not what he expected. "Removing the ice sheet led to lighter water molecules across East Antarctica", says Holloway, "opposite to the heavy peak I was aiming for." The cold water entering the ocean as the ice sheet collapsed was causing more sea ice to form around Antarctica, decreasing temperatures. Surprisingly, the scenario that produced the best fit with the ice core data did not involve any ice sheet collapse at all. It was achieved by dramatically reducing the area of sea ice around Antarctica. "This scenario matched both the magnitude of the heavy mass peak and how it varies between the individual ice cores across East Antarctica," comments Holloway.

I have to admit to being confused at this point in our conversation. If the West Antarctic Ice Sheet didn't collapse at peak warmth over Antarctica, then did it not collapse at all? And where did that missing sea level contribution come from? "My hypothesis is that the ice sheet did lose a substantial amount of ice, but later on, after peak warmth" says Holloway. "The West Antarctic Ice Sheet remains the prime suspect but the timing has changed."

Critically, there is no direct evidence of a collapse of the West Antarctic Ice Sheet in the last interglacial period. Prof. Eric Wolff from the Department of Earth Sciences, University of Cambridge, has recently made it his mission to change this. Thanks to a major research grant awarded by the European Research Council, Wolff will lead a field campaign in the 2018/2019 austral summer to drill an ice core from West Antarctica: the sample will be taken from the Skytrain Ice Rise, an independent ice dome close to the ice sheet edge.

He is confident that this new core will hold key information about the fate of the ice sheet during the last interglacial. As he explains, "Many models predict that the Ronne Ice Shelf needs to collapse in order to lose the ice sheet," referring to the floating ice shelf that is thought to act as a buttress to the West Antarctic Ice Sheet by holding back the fast-flowing streams of ice. "If the Ronne Ice Shelf did collapse [during the last interglacial period], it would show up in the ice core chemistry because open water would suddenly be 600 km closer to Skytrain." The Skytrain ice core will also provide invaluable additional data for climate model simulations like Holloway's, bringing scientists closer to pinning down the timing and nature of any West Antarctic Ice Sheet loss during the last interglacial.

Studies conducted by scientists like Holloway and Wolff show how ice sheets reacted to past climate change: this helps refine and improve predictions of future ice sheet melting, and the potential contribution to sea level rise. Clearly, timing matters. Many scientists believe that by warming our climate now, we are committing ourselves to future sea level rise from ice sheet melting. But how soon and how fast? Within our lifetime or in thousands of years?

Maybe modern Antarctic ice sheet collapse has already begun. West Antarctica is losing ice mass, particularly from the Pine Island and Thwaites glaciers, and the rate of loss appears to be increasing. However, as Wolff points out, the satellite data record is so short that scientists cannot tell whether this melt is "unusual and therefore alarming" or "happened before and stopped." Given the compelling evidence that the West Antarctic Ice Sheet did melt significantly during the last interglacial, it would be foolish to assume it will remain unchanged: the timing and scale of any future collapse remains dangerously uncertain

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Rachael Rhodes is a Marie Curie Fellow in the Department of Earth Sciences. Artwork by Holly O'Neil

The Power of Prediction and the Art of the Model

Mathematical models are powerful tools that can be used to solve many biological problems. **Stephen Cole** explores their history, uses and future potential

WHAT IS THE COMMON DENOMINATOR between cowpox, cancer, the stripes of a zebrafish and an STD inducing bacteria?

Answer: they have all been represented one way or the other by mathematical models.

Life is swarming with complexity, a dizzying storm of seemingly random events and fateful occurrences. Yet, the same way that a map is a model of a region, a biological model reduces a complex system to a set of equations describing its major components. These equations can then be used to understand more about how a process works, or make future predictions. A model, in effect, tames the apparent haphazardness of biological processes.

We are more familiar with mathematical models than we may think. In these troubled times of anti-vaxxing campaigns that oppose vaccinations, worrying gifs show how the spread of diseases such as measles changes depending on how many people are immunized. Those convincing graphics are elaborated through modelling – in fact, through quite an ancient type of modelling. In 1760, Swiss mathematician Daniel Bernoulli modelled for the first time the impact of inoculation, an older method of immunisation, on the spread of cowpox through a population. Now centuries later, the World Health Organisation leverage the predictive power of these bioinformatics tools to devise effective intervention strategies, such as estimating the threshold proportion of a population that needs to be vaccinated to stop a disease from spreading.

Yet, one should not be carried away by the possibility of mathematical models: as many other sciences plagued by the impossibility of experimental validation, debates can be fierce within the community while deciding if a model does or does not represent the biological process it is supposed to describe.

Enter, the zebrafish – and its infamous stripes. How do stripes form? How do tigers become striped but leopards spotted?

Some biologists championed the importance of random diffusion in pattern formation during development, claiming that if a signalling molecule diffuses away from a source, its local concentration would be proportional to the distance from the source; cells could then 'know' their position relative to the source by reading out the local concentration. Others believed this mechanism to be unfeasible, as diffusion is an inherently random, disordered process - so how could it give rise to such ordered patterns in a highly reliable manner?

However, in 1952, the famous mathematician and computer scientist Alan Turing published a paper entitled 'The Chemical Basis of Morphogenesis', in which he presented a model proposing one possible mechanism by which diffusion of molecules could reliably give rise to patterns. The so-called reaction-diffusion model relies on a negative feedback loop between two molecules, an activator and an inhibitor, which diffuse at different rates. Through this model, a huge variety of spatial patterns can be formed by fine-tuning the various parameters. Turing's model has been met with varied levels of acceptance by developmental biologists, with some sceptical about its relevance to real-world systems (just because a model can give rise to the observed patterns does not mean that is how it works in practice). However, other biologists have built on the essential concept of this model to explain phenomena such as stripe formation in zebrafish. The debate still rages on, 65 years after Turing's paper.

"All models are wrong, but some are useful," pondered the noted statistician George E.P. Box.

And indeed, cancer research is one field of study where complex modelling has taken off. In cancer, finely balanced interaction networks of genes, signalling pathways, metabolic pathways and cells become disrupted. By modelling these networks mathematically, we can get a better understanding of what causes loss of growth control in tumour. We can also predict how cancer cells will respond to therapies that target different components - by simulating what happens to a network if you get rid of one protein, for example. This reasoning can be applied to various other diseases where molecular networks are perturbed, such as type 2 diabetes and obesity. At the larger scale, new ecological models such as the Madingley model aim to capture interactions between all organisms in an ecosystem, with the goal of predicting how ecosystems will respond to changes such as global warming. This allows conservation efforts to be focused where they are needed, and assess the

"All models are wrong, but some are useful"
George E.P. Box

impact of human activities on biodiversity.

Cowpox, cancer and stripes: one could wonder how the modest – but pain inducing – bacterium *Mycoplasma genitalium* finds its place amongst that heteroclite ensemble. This microorganism counts about 500 genes, and in 2012, it was the first for which a model was developed for all of its proteins and their interactions. It is reasonable to expect that within the next couple of decades we will see similar whole-cell models published for simple eukaryotic cells, such as yeast. Such systems-level cellular models have vast potential, for instance in drug development, where they can be used to simulate the impact of a drug on cellular networks, and anticipate potential side-effects.

So, what can we obtain from computational simulation that we do not get from just doing hands on experiments? There are many reasons why experiments might not tell us all we want to know about a system. These may include the ethics and practicality of manipulating it, or the timescale over which an event occurs. For instance, hypotheses about evolutionary mechanisms can be difficult to test experimentally because evolution takes place so gradually, affecting species over millions of years. However, we can build mathematical models of the underlying processes, and these can provide great insight into the mechanisms of evolution and help to construct trees of evolutionary relationships. On the opposite end of the spectrum, molecular events like the folding of proteins from linear chains into an intricate three dimensional structure can happen too fast to be easily studied by experimental methods. Modelling protein folding using the laws of chemistry and physics can help us to understand more about how proteins fold and give insights into diseases that occur when proteins fold incorrectly, such as Alzheimer's disease.

More importantly, the fact that mathematical models are used for modelling processes at a wide range of biological scales reveals surprisingly similar underlying principles through nature. For example, similar models can be used to simulate population dynamics and the uptake and decay of drug molecules in the bloodstream. Models do more than reducing the 'noise' of life and making it more understandable: they can also reveal its common features that change the way we see the world

Stephen Cole is a 3rd year undergraduate studying Natural Sciences at St John's college. undergraduate. Artwork by Thierry Porter

I failed the fucking marshmallow test

I failed the fucking marshmallow test.
The real-life one, despite knowing its head
And eyes and long-term implications;
I failed the fucking marshmallow test.
An act of caring too much about caring
Or blatantly not caring, I'm still unsure
And though I know what I did it for
Its test-ness nature was unclear
Until the second I broke it – Oh dear;
I failed the fucking marshmallow test.
And now I don't know what the rest of my life holds
Or I know it too well -
I am physically destined to be unwell:
Impulsive, impatient, unlawful,
Short-sighted, misguided, just awfully
Selfish and trite -
Basically, I shouldn't be alive.
People like me should gradually fade
As an evolutionary trend;
I should die
Or find a good rock to hide under, at best,
Because I failed the fucking marshmallow test.

The Stanford Marshmallow Experiment, ran by Mischel in the 1960's and 70's, consisted of giving children a marshmallow and telling them they would get another of these treats if they resisted eating the one in front of them for a certain period of time. While subsequently tracking the participants thourought adulthood, researchers discovered major differences between the lives of those who ate the marshmallow and those who waited. For example, the latter group had higher SAT scores. Videos and re-enactments can be easily found on the Internet

9 AM lecture

Most benevolent lecturer,
Whose topic is Insect Hearing:
Your effort's truly fantastic
But I'd much rather be dreaming.

Insects and mammals have similar ways of processing sound but different structures for it. It is still unclear, however, whether insects can dream

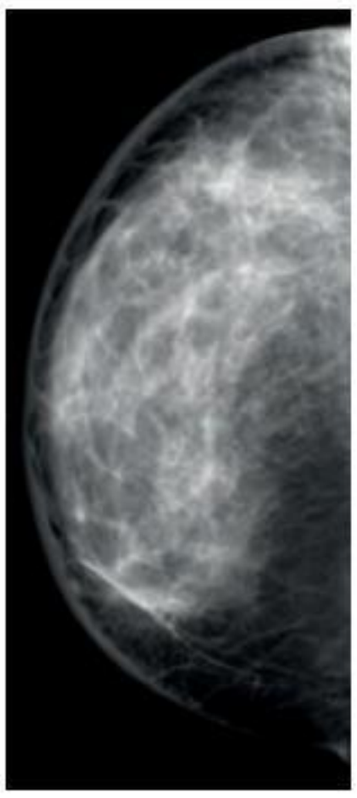
Nummulite

Brother of toxoplasmosis
(That mother caught, she swears,
Upon seeing a cat);

Little grey coin made of calc hats.
Nummulite. I see your
Skeleton so still down

There, where there once was a sea-rock,
Near the dam, in my pocket,
On somebody's nightstand.

Nummulites are the lenticular fossils of marine single-celled eukaryotes that were most prominent in the Eocene Epoch (55.8 million to 33.9 million years ago). Certain Nummulites formed very large convex translucent shells, which purportedly served to focus light on their symbionts, photosynthesising algae



Computerised Tomography can be used to determine the extent of identified breast cancers. While CT images of calcifications appear as white specks, certain aggressive, widely spread cancers look like a complex net of lit tissues. On occasion, breast calcifications are an early sign of cancer. Image from Harish et al. *RadioGraphics* 2007

A tiny univese

The breast is in its safe cocoon
Under the skin that coddles it
Lively like its owner is
Until the doorbell rings.

Oh breast you little moon
That shines under the skies,
Why have you webs under the skin?
Why have you stars inside?

The tiny dots a tablespoon full
Got spilled on mother earth
And so, as a curse,
Is born a tiny universe.

A sudden explosion –
Ticking, unwinding, unsown,
The minute heart of a cell,
Now a sprawling nebulosa.

Do not, little universe
With promises of wealth,
Take back our mother
And leave like Russia a deserted land.

Laia Serratosa is a Neural Systems and Computation masters student at the Institute of Neuroinformatics in Zurich. Artwork by Carys Boughton

The Museum of Zoology

The **Bluesci FOCUS team** took a peek behind the scenes and explored what the current renovations at the Museum of Zoology mean for the future of the institution

"My boys have asked to come to the Museum today [...] Feels like we have been waiting forever! So excited for it to open again," says a message on the Facebook page of the University Museum of Zoology, Cambridge. It has been nearly four years since the Museum closed its doors for refurbishment, and excitement is rising for its reopening. The wait is nearly over, for the Museum should reopen in 2018.

"When I first got here, the museum was looking a little jaded, a little ancient... Little had been changed in any sort of general sense since it was established in the 1960s. It looked ripe in terms of making it a more modern outfacing museum, making it accessible to a broader, more diverse general public whilst also retaining all the good features in terms of research and teaching," explains Professor Paul Brakefield FRS, Professor of Zoology and Director of the University Museum of Zoology.

Cambridge's Museum is not the only one to undergo changes. The Smithsonian National Museum of Natural History 'Dinosaur and Fossils' hall has been closed for renovation; the main hall of the Natural History Museum in London also went through refurbishment and saw Dippy the Dinosaur, a relic of the past, being replaced by Hope the Whale. Both institutions cite the importance of strengthening their voices in society, of mobilising their legions of specimens to bear witness to the theory of evolution and educating the public on ongoing, increasing threats to planetary biodiversity. In the current (and troubled) political context, what message will the new Museum of Zoology convey? **EL**

Museums and their message

What museums tell society goes beyond the exhibitions they put together and display. The audience who visits them, and the buildings that welcome them also define the message they convey and are a reflection of contemporary political and social environments. The first public French museum – Le Louvre - opened in the midst of the French Revolution. Suddenly this lavish space for Kings and Queens was filled with members of the public, and the walls of the palace bore witness to changing times. In 1759, not 40 years before, every prospective visitor to the newly opened British Museum needed to submit a written application to be allowed to visit. Entry for 'studious and curious persons' was thus confined exclusively to the educated and privileged, mirroring how knowledge was segregated within society. Later, as the British Empire marched through the world, artworks flooded into its museums and 'cabinets of curiosities'; the specimens themselves, plucked from conquered areas and beleaguered communities, unwittingly told tales of imperialism and prejudice. Renovations and refurbishments such as the ones undertaken at the Museum of Zoology do not usually take place in a social vacuum; they normally entail more than dusting off old specimens and applying new coats of paint. By changing their buildings, the specimens exhibited or their target audience, museums get a fresh voice; one that echoes or announces new evolutions in society. **EL**

Behind the Scenes:

An interview with Dr. Jason Head, Lecturer at the Department of Zoology and Curator of Vertebrate Palaeontology at the University Museum of Zoology

How is the refurbishing and moving of everything into the new museum space even going?

It's certainly been a huge challenge. I showed up here just over halfway done, so I walked into the middle of the process. As of now [22nd June 2017], half of the academic staff have moved in. Most of our collections – the spirits collections, our skeletal and fossil collections – have moved back into their new spaces. We are basically ploughing on full speed ahead to finish up the exhibit space and to get everything ready to go.

Charles Darwin on his beetle collection, in his autobiography: "...no pursuit at Cambridge was followed with nearly as much eagerness or gave me so much pleasure as collecting beetles"

And the whale skeleton?

The whale went up without a hitch – it was rather amazing! It is 150 years old, so it's the exact same age as the museum, and is a beautiful attraction both to students and to the public. I actually use it in my teaching, as it's a very powerful and engaging way to talk to students when you're standing under the skeleton - you want to tell the story of vertebrate evolution and you're looking at one that's 70+ feet long [21+ metres]. It's our logo and it's a great way to welcome people into the museum.

The flipper of an elephant seal. Whilst a seal's hind flipper's are used for propulsion, front ones like this are used like rudders, for steering

Did you visit many museums when you were a child?

As a child, I would go with my family to the Museum of Natural History at the University of Michigan. Because my mother was from Washington DC, every summer we would visit her family and go to the Smithsonian, where I would spend my time at the [National] Museum of Natural History. I ended up doing my undergraduate at Michigan working at the museum, and was a postdoctoral fellow at the Smithsonian – I was very privileged and lucky to be able to actually work at two of the places which have been so influential to me.

How long have you been the curator of vertebrate palaeontology at the University Museum of Zoology for?

I am just coming up on the end of my second year. Most recently before, I was at the University of Nebraska and before that, the University of Toronto. This is my fifth natural history museum!

As someone with so much experience, what do you think the purpose of museums is in the modern day?

I've said this before, and I say it without irony or sarcasm – I truly believe that natural history museums can save the world. We are at a very unique moment in human history where we have basically come very close to eradicating nature. There are 'wild places' in the world, but there is really no nature left if we're finding human chemical signals even at the bottoms of abyssal trenches and at the top of our atmosphere – there is no natural habitat where we have made no modification at some level. As we start to plan out the future for a growing human population, shrinking wild places and what that means for the quality of life for human beings, what we need is data on the recent and deep past of Earth's natural ecosystems – and the only places we find that now are at natural history museums. So, when I say natural history museums can save the world – literally, natural history museums can save the world.

I suppose that explains why you've worked in five of them.

Well…yeah. >laughs<

How do you think museums have changed in recent times with this conservation message? The Natural History Museum in London recently replaced its Diplodocus skeleton in its main hall with a whale and some more modern species. The University Museum of Zoology has of course been reorganised and refurbished – has it changed its

approach in a comparable way?

Conservation and the human ecosystem are new issues dealt with primarily through research and collections. Exhibits in most museums are generally still focussed on either things like holistic approaches to looking at biodiversity - which is the primary objective of our exhibit structure - or telling a narrative about the history of life through time, which is what you would see a lot of at the Sedgwick Museum across the street, where you have much more of a palaeontological approach.

Is this the right approach for museums to take? Or, if you had ultimate control, would you emphasise conservation in the University Museum of Zoology?

I think it's not 'either or', because we do need to educate the public as to how we've radically resurfaced what's left of the natural world and how we've changed ecosystems…but we also have to give them the classic education on things like the history of life and biodiversity. So including issues of more immediate concern and impact is important – and we do some of that as you'll see when the museum opens up to the public – but we also have to give them the inventory of life's diversity at the same time. We're a zoology museum, we focus on animals – a large part of the exhibit is basically demonstrating the diversity of animals alive today and in the past.

You mentioned the Natural History Museum in London – that's a stand-alone museum. It has a particular audience, which is the general public. We are a university museum, which means that while the public is a part of our audience, a large part of that public are the students at Cambridge. We use the collection more for teaching, more for interfacing with students and using it as a tool to help people develop an advanced education and understanding of the natural world, in addition to providing an experience to the public which aren't Cambridge students or staff. JM

The Fin Whale

"I went to Pevensey to see the whale, and when I got there, I could only see its tail/The tail was so long and the smell so strong it made people sick to stay there long." A skipping rhyme chanted by children by the whale carcass at Pevensey, 1865

In November 1865, a 70 foot whale washed up on Norman's Bay, near Pevensey. Being one of the largest mammals in existence, let alone in the North Sea, the finback whale was greeted by public amazement. Before the University of Cambridge acquired the skeleton in 1866, an estimated 40,000 visitors made the trip to its 'foul smelling' body, with songs and artwork quickly appearing. Since, it has been in the possession of the Museum of Zoology; until 2013 hanging eerily on the public walkway of the Downing complex.

Now, following 5 weeks of bone-by-bone dismantling, and many more for rehanging, the extraordinary creature has been redisplayed: suspended it in all its glory in the new lobby of the renovated museum, with a glass front to retain its place in the public eye. It now has a new backdrop of Rowena Whitehead and Chris Watson's 'ocean scape', a piece of music inspired by the whale. This otherworldly creation contains fragments from the whale's skipping rhyme sung by children from Pevensey schools, the sound of weddell seals, humpback whales and crustaceans in their natural habitat, traditional songs to sea deities such as the Yoruba goddess Yemaya, as well as poignant recordings of the sea on Norman's bay today.

In addition to being a dramatic space, the whale's position on the façade of the new museum is a powerful reminder to us that we need to protect and conserve the creatures on our planet. Finback whales are listed on both Appendix I and II of the Convention on the Conservation of Migratory Species of Wild Animals, but, despite there being only approximately 100,000 in existence, they are still today targets of harpooning and whaling.

The Museum of Zoology is still raising funds for the whale's conservation through the twitter campaign #raisethewhale. You can find stop-motion videos of the whale being dis- and re-mantled at the Ocean Song website: https://oceansongproject.wordpress.com/**MD**

Weighing in at more than 300 pounds and at a length of over 10 feet, Komodo dragons are the world's largest lizards

Saving Living Animals with a Lot of Dead Ones

Construction sounds echo through the room as the conversation with Professor Paul Brakefield FRS, Professor of Zoology and Director of the University Museum of Zoology, and Polly Hodgson, Project Manager at the Museum, unfolds. This soundtrack of thudding hammer and roaring machines is somehow the perfect score to the dreams and visions the team has for the new Museum of Zoology.

The voice of the Museum, its vision, is to bring together the general public, students, researchers and conservationists to celebrate, research and learn about biodiversity at a time when its protection is increasingly needed. In this quest, the team has a significant trump card: the Museum building itself.

Nested within the Department of Zoology, a stone's throw away from the Whipple Museum of the History of Science, the Museum of Archaeology and Anthropology and the Sedgwick Museum of Earth Sciences, the new Museum of Zoology is physically embedded within the Cambridge research and conservation communities. Indeed, the David Attenborough Building, where the Museum is situated, also welcomes nine NGOs and the Cambridge Conservation Initiative, a unique collaboration between the university and a number of international biodiversity conservation organisations. This unique location serves the Museum's ambition to become a local and national hub for research, outreach and conservation.

Dr Ed Turner, University Lecturer in the Department of Zoology and Curator of Insects in the Museum of Zoology, explains: "Having a museum so tightly linked with a number of conservation organisations on one hand and the research on the other hand is fairly unique, and that's a really exciting opportunity. It's a fantastic way of engaging people with conservation and research, and showing them the specimens that underpin both. This is what we will need to do to make people understand a bit more about how the natural world works, and why we should protect it."

With the new renovations, conservation will not just be the Museum's motto: it will take shape within the walls themselves. "The whole building was one of the worst across the Cambridge museums in terms of energy efficiency", explains Hodgson. "We retained many very special elements of the old Museum, the wonderful atrium, the beautiful display cases arranged by the original architect, Sir Philip Dowson; but now it has become a state of the art building for energy efficiency." Professor Brakefield chips in: "We hope to use this example to reach the audience and inspire them to think about how they can adopt conservation efforts into their own lives."

From the engineering to the outreach work, all areas were considered with respect to their conservation impact. One early project saw more than 3,000 sea snail shells being collected by the Cambridge Young Zoologists Club. These painstakingly gathered shells have been mounted on the external walls of the Museum, where they serve a new purpose: as a home for a variety of insects, especially solitary bees.

Not just a convenient household for lonely insects, these sea snail shells are a testament to, in Hodgson's words, "the small army of volunteers, many of [whom] are still working with us today," who helped making the renovation a reality.

"The vast majority are people who are just interested in helping out. They are of all ages and backgrounds, and a lot have got jobs in museums from their experiences", continues Professor Brakefield. Packing up specimens and handling precious bird skins are not the only perks associated with volunteering, for rare discoveries occasionally reward the enthusiasts. One of the volunteers spotted engravings on a dolphin skull while handling the specimens; in 2009 another found an egg originally collected by Charles Darwin himself on the HMS Beagle - and unceremoniously shoved by the naturalist into a (too small) box a few decades later.

Volunteers are only a small sample of the people that, the Museum hopes, will bustle and hustle inside the building. Researchers, teachers, students and the public are all welcome, and everything possible has been done to break down the walls between the different groups - sometimes quite literally. For example, visitors to the Museum will be able to see learning in action in the new undergraduate teaching rooms that adjoin the display areas.

The research conducted by the Department of Zoology will also occasionally be shown to the public, as displaying and communicating its own findings is also of paramount importance. The fantastic collection of cichlid fish from Lake Malawi will be a world-class demonstration of how beauty, outreach and science can be intertwined, extending scientific knowledge within and outside of the academic community. Over 700 species of cichlid fish populate the waters of the East African great lake, and the Museum counts a staggering collection of over 1,400 specimens. That

explosion of diversity, a celebration of the developmental and environmental processes at work in evolution, will be showcased through a special light display. Every one of the Lake Malawi fish held by the Museum has had its DNA sequenced, and evolutionary biologists from the Wellcome Trust Sanger Institute are using this information to better understand how so many species have developed.

Ultimately, this research will also underpin conservation efforts. "We are an archive of collections that have been made back into the past", Dr. Turner explains. "That makes our [collections] even more valuable, because it means you can use them as a way of assessing environmental change."

Indeed, a large portion of the collections in the Museum of Zoology are from the 19th century, a time bursting with the biological discoveries that laid the path trodden by modern biology. While it continues to welcome new arthropods from current research expeditions, the Museum's 1.2 to 1.4 million insect specimens largely come from donated private collections patiently assembled in the 1800s – including the beetles Darwin himself gathered during his undergraduate degree. This constitutes an unparalleled opportunity to study past biodiversity.

For example, the Museum holds specimens of the British Large Blue Butterfly, which went extinct in the UK in 1979. They were reintroduced in the '80s from European stock but the two British subspecies are long gone. "These specimens are invaluable, first because they are irreplaceable, but also because they teach a lesson", Dr. Turner carries on. As he explains:

"There is something about seeing something that will never be seen in the world again as a result of human action which makes conservation much more real to people."

By conducting genetic analysis on the Museum's specimens of extinct or rare species, researchers are given the opportunity to take snapshots of their decline from the moment that their habitats fragmented and their populations collapsed.

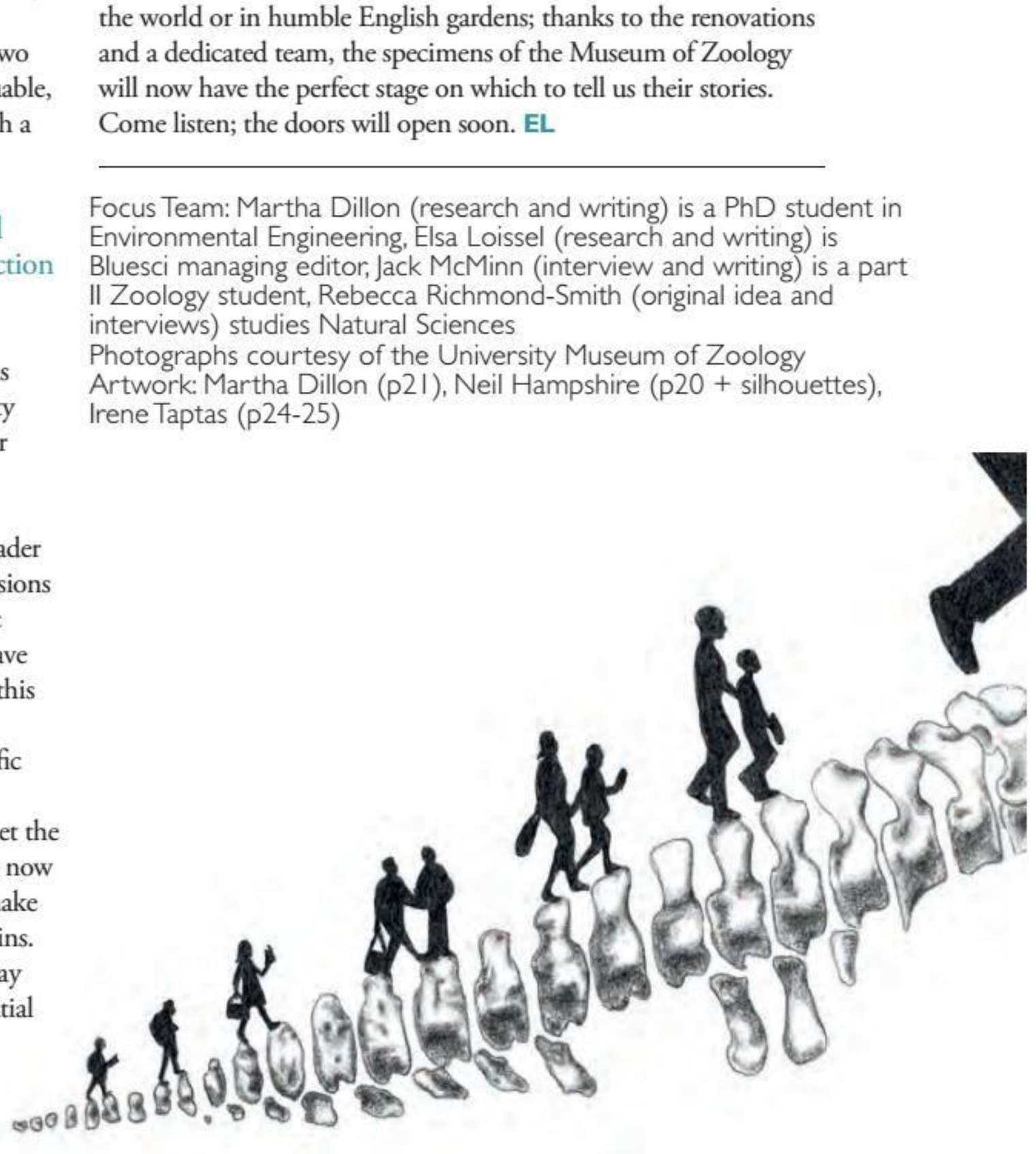
This genomics revolution has also brought changes in the blueprint of the Museum itself. As Dr. Preece, University Reader and Curator of Malacology, explains: "Major taxonomic revisions have resulted from the application of molecular phylogenetic techniques. This revolution is still ongoing, so the displays have been designed so as to be able to incorporate future work of this kind. For the purposes of using the exhibits for research, the displays will even be structured to accommodate new scientific discoveries in the field of classification."

Other new technologies have also been adopted that also set the project apart from traditional natural history museums. "We now have a world-class micro CT facility, which enables you to make 3D images of fossils and animals", Professor Brakefield explains. Micro Computed Tomography (micro CT) is a new 3D X-ray system that allows the imaging of samples with very high spatial resolution without damaging the structures. Dr. Preece describes one of their larger projects: "The DDF Bivalve Mollusc Project had two main objectives. To produce a database for all the bivalves in the Museum [a number upwards of 100,000] and to provide high quality images of all the reference specimens on which a particular species is defined." This digitisation follows in the footsteps of the long custom of zoologists and museums drawing and recording their specimens in great detail.

Perpetuating tradition while also preparing for the times to come is indeed the tight line the Museum has chosen to walk. In Dr. Turner's opinion, "museums have interesting lessons […] in terms of understanding the past, but also the future." The renovations may not be a rupture from tradition, yet they are firmly propelling the Museum into said future, with the department creating space to receive new collections. The Museum of Zoology will be the first to welcome specimens from hydrothermal vents (cracks in the sea floor were intense geothermal activity occurs), and showcase the extraordinary range of organisms that have evolved at the very bottom of our oceans.

They have been collected centuries ago, picked by the febrile hands of enthusiastic naturalists, discovered in exotic places across the world or in humble English gardens; thanks to the renovations and a dedicated team, the specimens of the Museum of Zoology will now have the perfect stage on which to tell us their stories. Come listen; the doors will open soon. **EL**

Focus Team: Martha Dillon (research and writing) is a PhD student in Environmental Engineering, Elsa Loissel (research and writing) is Bluesci managing editor, Jack McMinn (interview and writing) is a part II Zoology student, Rebecca Richmond-Smith (original idea and interviews) studies Natural Sciences
Photographs courtesy of the University Museum of Zoology
Artwork: Martha Dillon (p21), Neil Hampshire (p20 + silhouettes), Irene Taptas (p24-25)



Living in the Shadow of the Volcano

Inspired by the 'Volcanoes' exhibition at the Bodleian Library, Oxford (Feb – May 2017), curated by Prof David Pyle, **Victoria Honour** unearths new information about volcanic eruptions

Turner's painting 'The Lake, Petworth' features a stunning sunset. The rich colours he saw in the sky would have been the product of aerosol particles thrown into the atmosphere by an eruption in Indonesia in 1815. A 2014 study in the journal Atmospheric Chemistry and Physics found that the red-green ratio in great masters' paintings of skies correlated with the predicted volcanic aerosol content in the air following 50 historical eruptions

HUMANS HAVE LIVED alongside volcanoes throughout our history. Fertile volcanic soils, dramatic scenery and warmer ground temperatures have long drawn people to volcanically-active regions. Belching, fountaining and spewing-out hot lava, volcanoes fascinate and intrigue scientists, artists and the public alike. Tourists can safely and relatively easily visit many erupting volcanoes; tour operators will take you to see quietly oozing lava or small puffs of ash. Or, if you're looking for something a little less adventurous, Google Maps has developed a Street View allowing you to explore inside a volcano from the comfort of your own home! In 2017, by choice or otherwise, half a billion people live near volcanoes that are classified as having a 'high risk' of eruption. Understanding volcanoes and their potential impact on society is therefore more important than ever.

Today, volcanologists have an extensive array of high-tech scientific tools with which they can study volcanoes. These tools have only been developed in the last century and so the accumulated body of recorded data on volcanoes has a limited historical extent. In light of this, volcanologists have recently begun to study cultural and historical records of past eruptions. Such observations complement modern volcano monitoring techniques by extending the time-window within which volcanologists have knowledge of volcanic eruptions.

Very large explosive eruptions are rare and few have occurred since the development of modern volcano monitoring techniques. The most recent major eruption was at Mount Pinatubo in the Philippines, which explosively erupted in June 1991. Volcanologists were able to directly observe vast quantities of gas and particulates injected into the Earth's stratosphere (more than 10 km high). These spread across the globe in less than three weeks and acted as a reflective blanket in the atmosphere, cooling the planet by 0.5°C (on average) for 12 months. But there have been much larger eruptions in human history. Diaries, ship logs, paintings, newspapers, colonial records, stories, poetry can all give volcanologists evidence of similar processes to those observed during the eruption of Pinatubo, and they document the global consequences of larger eruptions. Using these historic sources to understand the impact of large past eruptions may provide new clues about how similar size events could globally impact societies today.

In 79AD, Mount Vesuvius dramatically erupted in the heart of the Roman Empire (just outside the city of Naples, Italy). Pliny the Younger's subsequent account, recorded in letters to a friend, gives a remarkably accurate description of the explosive eruption:

"It was not clear at that distance from which mountain the cloud was rising [it was afterwards known to be Vesuvius]; its general appearance can best be expressed as

being like an umbrella pine, for it rose to a great height on a sort of trunk and then split off into branches, I imagine because it was thrust upwards by the first blast and then left unsupported as the pressure subsided, or else it was borne down by its own weight so that it spread out and gradually dispersed."

His description resulted in modern volcanologists classifying this type of large explosive eruption as being of a 'Plinian' style.

Mount Tambora, in Indonesia erupted explosively in 1815. It has the infamous title of being the largest eruption in the past 2000 years (modern volcanologists know this from looking at the volume of rocks that were erupted). "The year without summer" followed in 1816, affecting areas of China, Europe and the east American coast. During this summer, Mary Godwin, her husband-to-be Percy Shelley and Lord Byron were on holiday at Lake Geneva. They were trapped indoors by persistent rain and decided to hold a competition to see who could write the best horror story. Mary's entry, 'Frankenstein', went on to become a literary classic and is a truly significant cultural outcome of the eruption. Further north, away from all the rain, there were accounts of the Arctic sea ice breaking up and creating an ice free passage between the Atlantic and Pacific Oceans in 1816. Three years after the eruption, a British expedition arrived to explore this much sought-after north-west passage but the wind direction had returned to normal and their records show that the sea ice had fully re-solidified, preventing the passage being found and exploited as a trade route between Europe and Asia. The bad weather caused by the Tambora eruption was so prevalent that William Dunn, who kept a weather diary in Eastern England, remarked in July 1816 that there was "...no rain! The first day without rain for 24 days". These diary accounts and literary records highlight a major feature of large explosive eruptions: their atmospheric impacts cause them to go from localised hazards affecting local populations around a volcano, to truly global phenomena. The historic sources can be used by modern scientists to reconstruct the weather patterns crossing Europe in the wake of the Tambora eruption. This allows scientific models predicting the impact of large volcanic eruptions to be checked against the outcomes of real volcanic eruptions.

Prominent European artists such as William Turner and Caspar David Friedrich painted works illustrating spectacular red and orange skies seen in the wake of the 1816 Tambora eruption. The unusual sky colours are caused by sulfur dioxide released by the eruption condensing and forming droplets of sulfuric acid in the atmosphere. These scatter the sun's light and once it has sunk below the horizon, the scattering effect produces dramatic coloured sunset skies. By measuring the ratio of red to green in the paintings of sunsets by artists of the era, scientist can begin to get an estimate of the aerosol levels in the atmosphere in the years following an eruption.

The Tambora eruption was followed in 1883 by the explosive eruption of Krakatoa in Indonesia. The sunsets from this eruption prompted newspapers of the time to publish dozens of letters from the public describing the phenomena. Alfred Tennyson witnessed the global impact of the eruption and, in 1892 it inspired him to write a descriptive 'end-of-days' opening to his 'St. Telemachus' poem, recounting how "thro' many a blood-red eve…, The wrathful sunset glared". The event was also witnessed by Edvard Munch, whose background to the famous 1883 painting 'The Scream' was inspired by the volcanic sunsets. These cultural works allow volcanologists to see the global extent of the eruption's impact depending on where the artists were living at the time.

These massive explosive volcanoes dwarf any eruptions monitored in the age of modern instruments. Today we have a growing knowledge of how and why volcanoes erupt, the global hazards and consequences that they pose to society. Observations of unique explosive eruptions from historical documents - including those recorded by eyewitnesses- are invaluable to volcanologists as they provide real-life evidence of the global ramifications of these potentially devastating events. The better we understand volcanoes, the better society can prepare for future explosive eruptions

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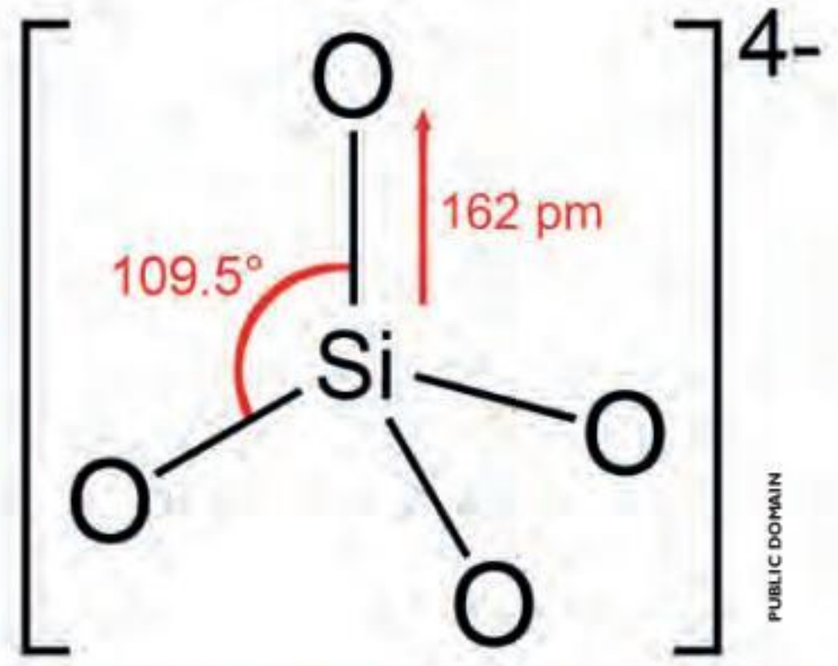
Victoria Honour is a PhD student who works on Igneous Petrology in the Department of Earth Sciences

Humans are still discovering new volcanoes. A 2017 remote survey of the West Antarctic Rift System found 91 new volcanoes under the ice sheet, some over 3,000 metres high. Image, Mt. Erebus in Antartica

The Magic Mineral

Ramya Gurunathan clears the dust around the rise and fall of asbestos



PUBLIC DOMAIN

Asbestos is the name for a group of naturally-occurring, silicate minerals (minerals containing the SiO_4 group), which are composed of long, thin, fibrous crystals. Asbestos is abundant on every continent, and thus is relatively cheap and easy to mine

WITH A NAME THAT TRANSLATES to 'inextinguishable and unquenchable' in ancient Greek, this naturally-occurring, fibrous mineral was considered to be the stuff of dreams. Asbestos, the once common construction material, is nowadays notorious for causing pulmonary diseases after long exposure. Even today, the sight of asbestos removal vans is not the rarity one might wish, and asbestos-related lung cancer still claims about 2,000 lives a year in Great Britain alone.

However, it was way back in the first century AD that the damaging effects of asbestos inhalation were first documented. Strabo, a Greek geographer, and Pliny the Elder, a Roman naturalist, both independently noted that due to a 'sickness of the lung', it was unwise to purchase slaves who had worked in the asbestos quarry, as they were likely to die young. Pliny the Elder even suggested using bladder skin as a respirator to prevent slaves from inhaling the asbestos dust. So why, then, did the UK only start to restrict the import and use of asbestos in the mid-1980s? Why is asbestos use still not banned in the US? Understanding the impressive material properties of asbestos provides some insight into this question. And the long-enduring use of asbestos in building and manufacturing around the world is a rather disheartening tale of insidious industry practices and slow regulatory response.

The attractiveness of asbestos in industry is due in part to its chemical inertness. Asbestos fibres do not evaporate and are insoluble in both water and organic solvents like benzene or alcohols. Most forms are resistant to acid, unreactive with many materials, and are non-flammable. In fact, the fire-resistant properties of asbestos astounded early civilizations. In ancient Greece and Rome, fabrics woven from asbestos fibres would be 'cleaned' by tossing them into a fire, as they would come out unharmed and slightly whiter. Further, bodies of the dead were wrapped in asbestos shrouds before being cremated to keep the ashes of the body separated from the funeral pyre's own ashes.

But the 'magic' of this mineral, for most industrial purposes, stems from its notable physical properties. Asbestos inhibits the flow of heat and electricity while also absorbing sound, lending itself to use in the insulation and sound-proofing of buildings. The tensile strength of asbestos fibre, which refers to the maximum stress a material can withstand when pulled at its ends, is similar to that of steel wire. Finally, it is lightweight, can be applied in a sprayable format, and binds well to other construction materials. Asbestos appears, then, to be an ideal building material: strong, insulating, fire resistant, corrosion resistant, soundproof, easy to install, plentiful and cheap! As a result, in its heyday, asbestos made it into over 3,000 household, automotive, and industrial products including pipe insulation, cements, brake and clutch linings, ropes, and flame-retardant paper.

The Industrial Revolution brought a real boom in asbestos production with the emergence of steam-driven machinery to mine and transport raw materials. By 1900, asbestos was being mined across the globe in Canada, the UK, Australia, Zimbabwe, and South Africa. In 1898, a report summarizing 60 years' worth of health and safety inspections in England's asbestos mills noted "widespread damage and injury of the lungs, due to the dusty surroundings". Then in 1906, at London's Charing Cross Hospital, the first death of an asbestos worker due to pulmonary failure was documented, the autopsy revealing large amounts of asbestos in the 33-year-old's lungs.

Not all asbestos-related diseases are cancers. Non-malignant ailments include asbestosis (scarring of lung tissue) and damage to the pleura, a double-layered membrane which lines the outer lung and inner rib cage. Asbestos exposure can cause unequal thickening of this membrane or induce plaque buildup in the gap between its layers, leading to severe shortness of breath. Malignant ailments include lung cancer and mesothelioma, cancer of the mesothelial cells that make up the pleura. Asbestos can cause these cancers in two ways: by directly interfering with the cell division process, or by triggering the release of oxygen and nitrogen in their reactive forms. These reactive molecules help regulate the airway and defend against bacteria, but can also cause mutations to the DNA, which can lead to aberrant cell growth.

Despite early knowledge of the medical risks, the production of asbestos-containing goods grew and grew until the 1970s. World demand for asbestos reached its

O'RAN MAGUIRE

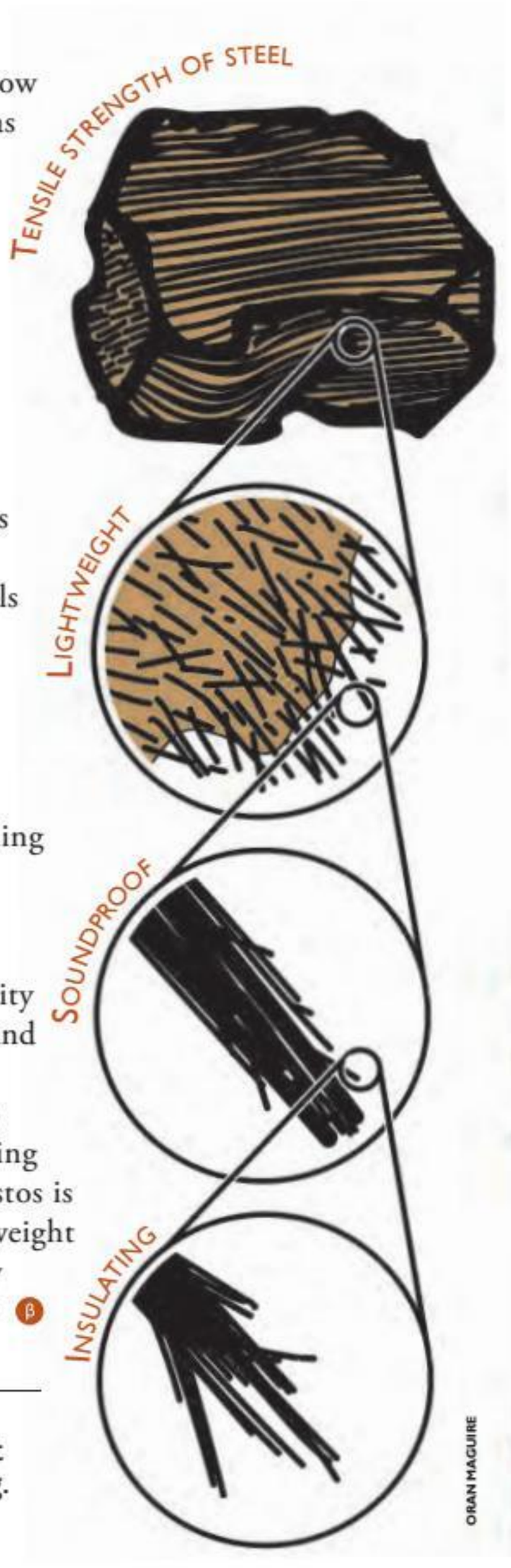
peak in 1977 with 4.8 million metric tons of asbestos produced. Full bans on the use of asbestos were implemented in the UK by 1999 and across the EU by 2005. Today, over 50 countries around the world have banned asbestos use, with Canada, formerly one of the largest producers, scheduled to ban the mineral next year. There is, as of yet, no ban in the US, although all asbestos mines have now been closed.

Regarding these bans, the remaining question of "What took so long?" is the subject of the book Defending the Indefensible by Geoffrey Tweedale, former Professor of Business History at Manchester Metropolitan University, and Jock McCullough, Professor of History at the Royal Melbourne Institute of Technology. As part of their research, they obtained a copy of the Turner and Newall (T&N) asbestos company archive. Through studying almost a million documents, they discovered that major asbestos companies like Johns Manville and T&N had conducted studies in the 1930s which showed the damaging effects of asbestos exposure, but had chosen not to publish the results.

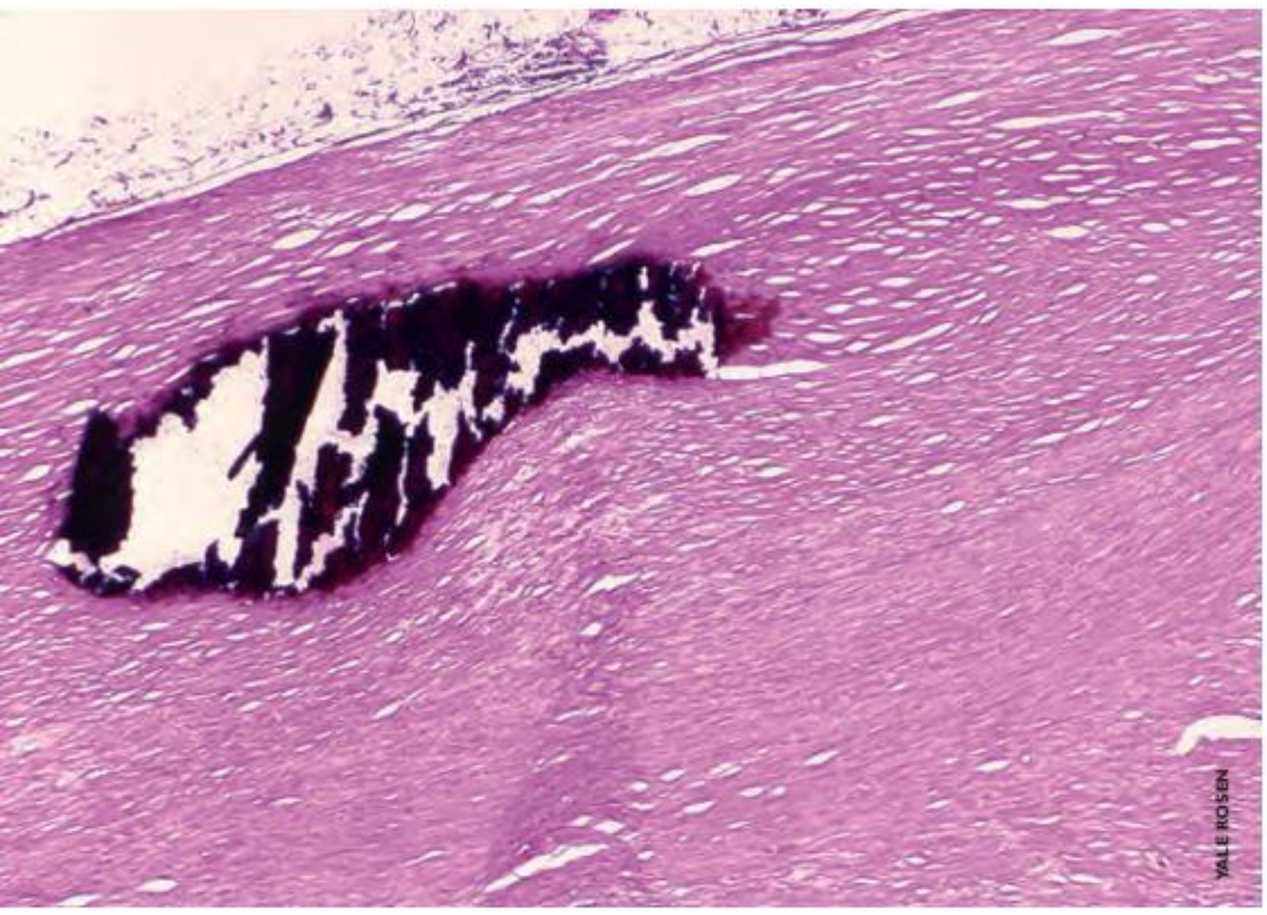
Despite this commercial suppression, large amounts of independent research brought the health impact of asbestos exposure to the fore, such as a study by New York physician, Irving J. Seikoff, which showed heightened levels of asbestosis, lung cancer, and mesothelioma in insulation workers. Internal documents at Johns Manville with the title "Discredit Seikoff" surfaced years later, and exposed an industry practice of misrepresenting uncertainties in these studies in order to undermine them. Asbestos industries sought to gain control of health and safety research by establishing their own institutions with benign names that did not suggest industry ties, one example being the Institute of Occupational & Environmental Health at McGill University set up by the Quebec asbestos mining industry. Tweedale and McCullogh's book suggests that the slow regulatory response to asbestos use was also linked to the fact that asbestos-related illness disproportionately impacted the working class. Tragically, workplace casualties in manufacturing jobs were regarded as somewhat of a norm.

Technological advances in materials have been integral to making our buildings taller, computers faster, and water cleaner. And the coming decades promise more exciting, new materials technology, including "smart" materials capable of sensing and reacting to changes in the environment, and also nanomaterials with applications in medicine, energy harvesting, and electronics. The history of asbestos highlights the importance of maintaining independent environmental, health, and safety organizations to assess these materials. It also underlines the importance of democratic accountability and finding ways to educate workers and consumers about (often technical and nuanced) safety risks. If we are able to take something positive and encouraging from this account, the decline of asbestos is proof that a harmful industrial heavyweight can be toppled by conscientious safety research and strong reactionary policy β

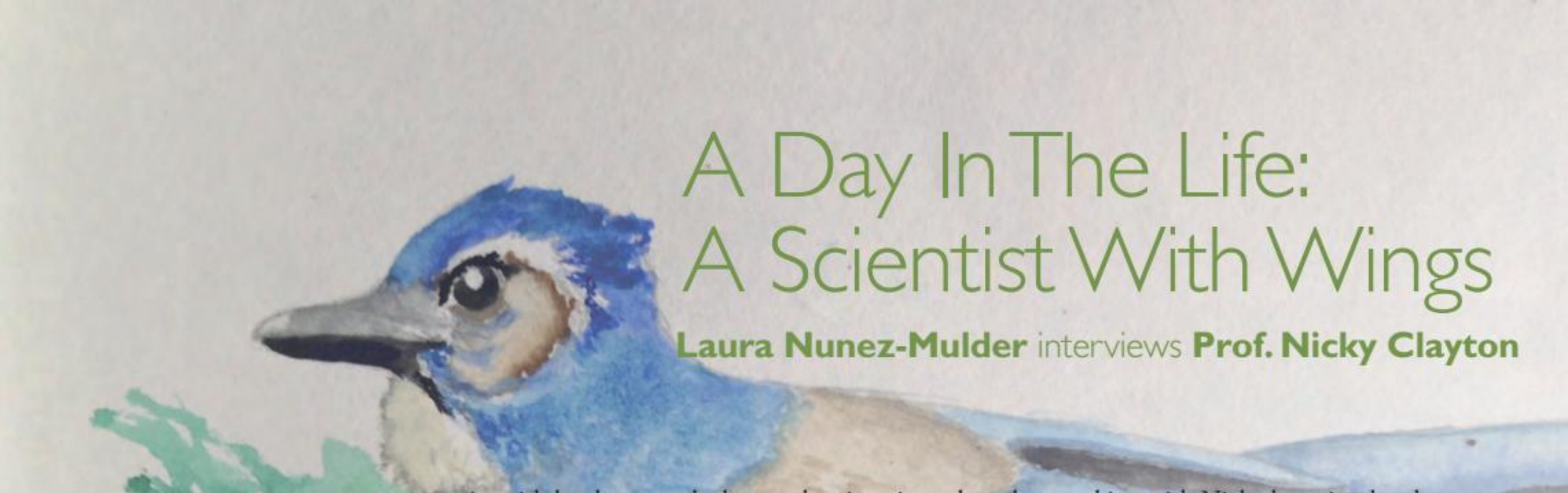
Ramya Gurunathan is an MPhil student at the Centre for Scientific Computing.
Artwork by Oran Maguire



The structure of asbestos lends it lots of useful properties



Asbestosis in lung tissue, severe pleural fibrosis and a dark, focal calcification. Asbestosis, which can be contracted by asbestos inhalation, involves chronic inflammation and scarring in the lungs



A Day In The Life: A Scientist With Wings

Laura Nunez-Mulder interviews **Prof. Nicky Clayton**

PROFESSOR NICKY CLAYTON sits with her knees tucked up and her feet on the sofa, cradling her cup of coffee in her hand. "I've always been interested in birds, from as soon as I could start walking. I'm a movement junkie. I wanted to fly, to be like a bird. I've got invisible wings – can't you see them?" She shimmies, and smiles. Nicky may be a Professor and a Fellow of the Royal Society, but she is also dancer, an artist, even a bird – and these parts of her are never far from her work.

The Professor of Comparative Cognition in the Department of Psychology at the University of Cambridge, Nicky Clayton, is a paradigm-shifter. Her work has challenged the assumption that cognitive abilities such as planning, reminiscing, understanding the minds of others, are unique to humans. Previously, only apes were thought to come close to human intelligence. Now, Nicky's 'feathered apes' have joined the platform: the corvids, a family of birds that includes crows, jays, and magpies.

At the beginning of Nicky's academic trajectory, she "felt like a second-class citizen" in the field comparative cognition. "Memory research was mostly conducted with rats and mice, so why bother with birds? And secondly, food caching research was really focused on spatial memory," rather than episodic memory, which we use to remember past events – what happened, when, and where. Then, in 1996, she met Tony Dickinson at a conference, while she was fielding questions from an audience. Nicky remembers that first encounter well. "Tony stood up and said, 'Animals don't have episodic memory.' 'How do you know?' I asked, which is my go-to question for getting to the bottom of scientific understanding. He said, 'There is no evidence for it. And I can't think of a functional reason why it would be beneficial.'" Nicky responded with an example from her subjects at the time, the California scrub-jays. They cache food all year round, some perishable, in the variable weather conditions of California. If a scrub-jay could keep track of which food it had cached, and how long ago – as well as the location – they would be able to make the most of every cache. Dickinson was swayed by her argument. "I think of people as animals, by the way, and I think of him as an owl. In that moment, he had a face like a wise snowy owl." Nicky shows me a ponderous, owl-like expression. Their collaborative paper, 'Episodic-like memory during cache recovery by scrub-jays', was published in Nature two years later.

As evidence for advanced cognitive abilities in corvids accumulated, Nicky teamed up with her husband to compare them with apes. Nathan Emery has a background in primatology, but working with Nicky has stimulated an interest in her field, too. "He became interested in birds because I would contradict him every time he started a sentence with, 'Apes are special because…' He's not a bird nerd like I am, but he became fascinated because I was always saying, 'But birds can…'" Together, Nicky and her husband reviewed the ways in which corvids can indeed match the abilities that formerly made apes 'special'. The review was published in *Science* in 2004.

While this is a fascinating topic of conversation, the medical student in me has to ask: why is it important to understand how birds think? "If you want to know how humans think, you don't want to only study humans. For example, if I want to know how a computer works, I don't want to restrict my studies to Windows PC, but also look at Apple Mac computers. Does that make sense? The similarities and differences give better insight into how it works, what limitations and constraints there are."

Nicky offers me a real-life example from her work. "Humans suffer from temporal myopia: we overvalue our current state of desires, and we think that the past as we remember it is an accurate representation of what happened. Both are fallacious. Both are heuristic constraints. But food-caching corvids are less constrained by their current desires." They are able to cache regardless of how hungry they feel – an evolutionary necessity to caching behaviour. As humans, however, our memories of past experiences, and therefore our choices for the future, are influenced by how we feel in the moment. "We are worse at dissociating from our current state." The comparison to food-caching corvids led Nicky's former PhD student, Lucy Cheke, to design an experiment on menu choices, the results of which has implications for medical research into obesity. "This is one way in which investigating how birds think has deepened our understanding of how humans think. Do you see?" I tell Nicky that she has made convert of me.

Nicky's affection for her feathered subjects is apparent. In 2000, she agreed to move to Cambridge on one condition – "I must bring the scrub-jays. It's scrub-jays and Nicky, or no Nicky." I am fiercely curious as to whether she has favourites, but her response is neutral. "I don't like the word 'personality' because I sound like I'm anthropomorphising. But they are all different. Wiggins is shy. She's the creative one. She's an architect; she builds walls." Wiggins is a Eurasian jay, as is Romero, "a fantastic mimic". Nicky has exchanged fond words with Romero on camera, available

online under 'J' of the Animal Alphabet produced by the University of Cambridge.

But these days, Nicky's academic trajectory is taking her away from corvids and into the social cognition of humans – children and adults – much of it inspired by her 'other life' as a dancer, performer, and cofounder of The Captured Thought. "I'm interested in the bigger picture. If something is not uniquely human, then you need to study it from both [human and non-human] directions." Did Nicky foresee her research taking this direction? "No… because you have to let ideas grow organically. A lot of it is inspired by my arts background as well as my science background," she adds. Nicky is the first Scientist in Residence at Rambert, the contemporary dance company, and founded The Captured Thought – a combination of talks and performances on the theme of imagination and mental time travel – with her tango partner Clive Wilkins, who is Artist in Residence in the psychology department. Sometimes, the two of them perform magic, and "what it reveals about psychology and perception is fascinating. If we were able to follow every causal relationship in front of us, then magic wouldn't work. But, because our brain is constantly anticipating…" Nicky completes the sentence with an expression that invites me to agree that it really is amazing. Her enthusiastic curiosity leads her research down the path of social cognition – for now, at least.

> "I never imagined I could combine my life as a scientist and my life as a dancer."

Just as Nicky's artistic side permeates her research, so her research saturates her creative work. Nicky looks delighted as she tells me, "I never possibly imagined I could combine my life as a scientist and my life as a dancer." In 2009, she was asked to join the creative team at Rambert for a work called 'The Comedy of Change', a celebration of Darwin's 'On The Origin of Species'. "I was searching for things that were both true of Darwinian processes but also themes that inspire dance. I don't think that could have been done by someone without the scientific knowledge." To use words from the Artistic Director Mark Baldwin, Nicky has given "intense educational input into [the] choreography" at Rambert ever since. Meanwhile, she tours the world with The Captured Thought. She and her tango partner often talk about "prospective flexibility – something that applies to both memory and dance. Memory is made for the future." In Professor Nicky Clayton, art and science are inextricable.

Of course, leading two lives makes for a busy schedule. In passing, Nicky mentions recent work in the Tate Modern and in New Zealand, and still more upcoming trips to Plymouth, Michigan and New York. Some trips are to give lectures on her area of expertise, the mentality of corvids. Others are with The Captured Thought, to perform and inspire, in venues that range from galleries to psychiatry conferences. It must be hard to pin down what 'a typical working week' looks like, but Nicky gives it a shot. "Things are fluid – there are manuscripts to write and to comment on, there are meetings about experiments, there is the boring answering of emails that we all have to do." Here and there, she choreographs for Rambert, and runs tango workshops. Does she spend much time at the aviary with the jays and the rooks? "Not as much as I would like."

Today, only two of the 25 California scrub-jays that moved with her to Cambridge – the stars of the paper on episodic-like memory – are still alive. "But," Nicky tells me, "for an 80g bird to live that long is a remarkable feat." At the beginning of her career, when the scrub-jays of Davis, California were still far away, Nicky could not have known the importance of the paradigm shifts that her lifelong interest in birds would lead to. "Part of science is to look at unknowns. The fascination is getting these puzzles. It's not about showing how clever a jay, a rook, a jackdaw is, but about looking at the pattern of similarities and differences. We learn more from errors or mistakes than from positive successes. In tango, there is a motto: where mistakes become moves." Professor, 'bird nerd', dancer – there is incredible depth to the woman before me, curled up on the sofa with her cup of coffee

The Clayton group has shown that California scrub-jays, *Aphelocoma californica*, are capable of planning for the future no matter how content they are in the present, a quality once thought to only exist in humans

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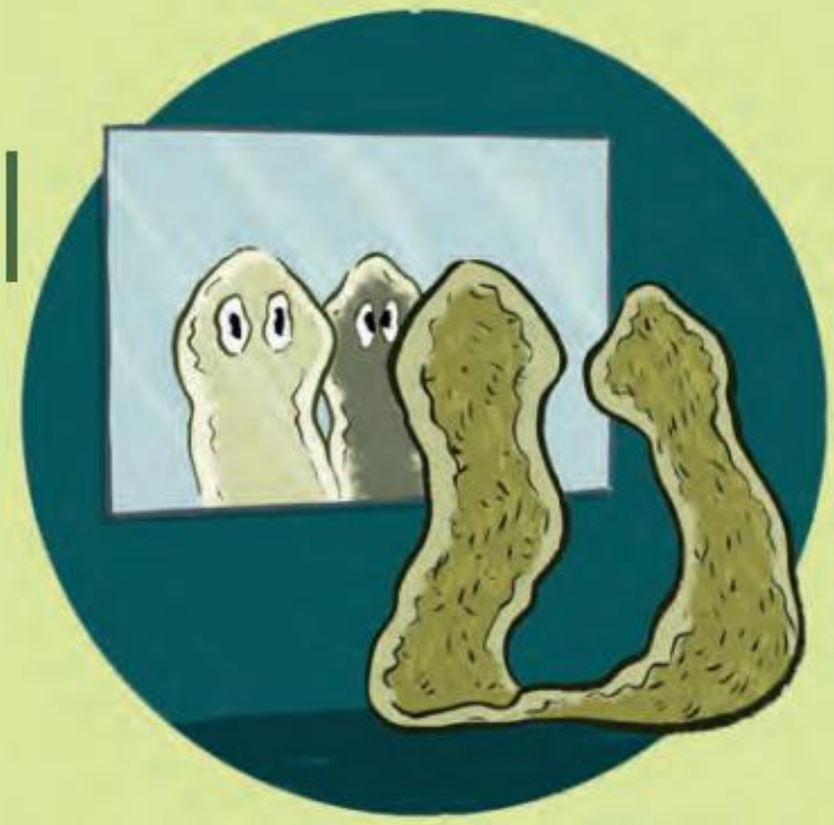
Weird and Wonderful

A selection of the wackiest research in the world of science



Felicia, the Atomic Ferret

IN 6 BC, CAESAR AUGUSTUS SENT FERRETS to the Balearic Islands to control the rabbit plagues. In 1971 AD, Felicia the ferret was dispatched by the US Atomic Energy Commission to clean the pipes of the National Accelerator Laboratory. Highly inquisitive and built for navigating small spaces, the creature was perfect for the role of 'atomic age pipe cleaner'. Costing $35 and 15 inches long, Felicia helped to clean 300-foot pipes in the Meson Laboratory building. All four miles of pipes were welded together, ready for an energy beam to speed across their four miles 70,000 times in 1.6 seconds.

After Felicia dragged a string through the pipes, scientists would tie a swab dipped in chemical cleanser to said string. When the swab was pulled through, it would emerge from the other side covered with dust. Felicia was crucial to the operation – even a small amount of dust would interfere with the energy beams going through the pipes. Living up to the British stereotype of eccentricity, it was visiting scientist Robert Sheldon who originated the idea. He drew inspiration from the use of ferrets by poachers on English estates. Will the pampered ferrets of today continue to live up to the inspiration of Felicia? EW

The Next Stage of the Avocado Revolution?

WHETHER SMAHES ON TOAST, chopped in a salad or mixed into guacamole, one thing is for certain: Britons are going bananas for avocados. It can only be good news that M&S has announced that their avocados will be receiving a trendy new makeover. Instead of labelling them with plastic stickers, M&S is trialling lasers to print labels onto avocado skins.

Laser labelling works by removing a layer of avocado skin, causing the skin to retract and leave a mark. The new labelling not only gets around the tricky problem of getting plastic stickers to stick to slippery avocado skin, but could be good for the environment too. According to M&S, replacing traditional sticker labelling with lasers would save 10 tonnes of paper and five tonnes of glue per year. M&S says if laser labelling avocados is effective, they may start laser using it on other products, possibly including lasering pumpkins with scary faces for Halloween. Laser labelling is not restricted to the UK – elsewhere in Europe, the Dutch supplier Nature & More and Swedish supermarket ICA are running trials lasering avocados and sweet potatoes. Could this latest phase in the avocado revolution signal the start of a broader revolution in how we label fruit and vegetables? JW

Worm with Two Heads Leaves Scientists Leaves Scientists Scratching Theirs

'TWO-HEADED CREATURES FROM SPACE' may sound like science fiction, but that is exactly what scientists found when they retrieved a sample of flatworms from the International Space Station.

Planarian flatworms are soft-bodied invertebrates. They possess remarkable regenerative abilities: chop them up into pieces and each piece can regrow into a new, fully-formed worm. Scientists wanted to see how microgravity and micro-geomagnetic fields experienced in space would affect this regenerative process.

They sent 15 worm fragments (with heads and tails amputated) to the International Space Station for five months, whilst a control group remained in spring water on Earth. Much to the scientists' surprise, one of the space-travelling worms returned having grown a head at both ends – an extremely rare event on Earth. They amputated the two heads and were even more surprised when the worm body regenerated both heads. This demonstrated that the major body-plan modification was stable and persisted even when the animal returned to Earth. The space-travellers also exhibited changes in microbiome composition and phototaxic behaviour: the microbial community living in and on these worms was very different to that of the earthbound control worms, whilst their movements in response to light were less consistent than the controls'.

The regeneration of these flatworms is more than mere curiosity. They offer insights into how physical forces can influence biological systems, suggesting that microgravity and hypomagnetic fields (an extremely weak magnetic field) could be applied to regenerative medicine. But before we make the exciting leap to humans, this observation was only made possible by the flatworm's amazing biology, so NASA does not need to worry about making two-headed spacesuits any time soon! BY

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